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THE AGE OF THE WORLD

THE
AGE OF THE WORLD

BY THE LATE

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PREFACE

THERE is no conclusion of science more firmly established than the high antiquity of the globe, and there is, perhaps, none more highly educative and better fitted to enlarge and elevate the conception of the universe and of the methods of Creative Power. Yet to the majority of the people of this country this great teaching is unknown, and by a large number who do know it, and who do not withhold assent, it is treated with indifference.

If the exposition and appeal contained in the following pages increase the number of those who give heed to the teachings of the record of the rocks, a life-long desire of the author will be achieved.

J. L. L.

LONDON, 1913.

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CONTENTS

PAGE

PREFACE 5

CHAPTER I

IMPORTANCE AND NEGLECT OF THE SUBJECT . . . 9

CHAPTER II

THE LARGER CHRONOLOGY—THREE PERIODS—MANKIND'S INDEBTEDNESS TO GEOLOGY 16

CHAPTER III

ESTIMATES OF GEOLOGICAL TIME—PHYSICAL, ASTRONOMICAL, BIOLOGICAL, AND CHEMICO-GEOGRAPHICAL ESTIMATES 25

CHAPTER IV

THE GEOLOGICAL ESTIMATE 35

CHAPTER V

THE GEOLOGICAL ESTIMATE—*continued* 44

CHAPTER VI

EARLY CLIMATAL CONDITIONS 55

CHAPTER VII

THE WORK OF GEOLOGICAL TIME—PALÆOZOIC . . 66

CONTENTS

CHAPTER VIII

PAGE
THE WORK OF GEOLOGICAL TIME—NEOZOIC 74

CHAPTER IX

BIOLOGICAL DEVELOPMENT—PALÆOZOIC 84

CHAPTER X

BIOLOGICAL DEVELOPMENT—NEOZOIC 93

CHAPTER XI

IMPERFECTION OF THE GEOLOGICAL RECORD—PERSISTENCY 104

CHAPTER XII

BIOLOGICAL CHANGES AND EXTINCTIONS 114

CHAPTER XIII

CAUSE OF BIOLOGICAL CHANGES 122

By the courtesy of the Victoria Institute the author has been able to use matter contained in his communications to that Society.

CHAPTER I

IMPORTANCE AND NEGLECT OF THE SUBJECT

THE age of the world, though a subject of vast importance, is little thought about, with very few exceptions, by even the thinking portion of the community.

When it is considered that the view taken of the age of the world, whether it be small or great, affects the mental conception both of the greatness and character and of the methods of working of the Creative Power, the importance of the subject will be at once recognised, and this importance seems to justify an endeavour to press it upon public attention.

A hundred years ago the story of the earth could not have been told. Although the constellations had been devised, the heavens mapped, and the more conspicuous stars numbered and named; although the character and motions of the planets were known and the times of the eclipses could be determined; although the globular form of the earth and its movements both of rotation around an axis and of revolution round the sun were well-established facts, and although, moreover, gravitation had been discovered and Newton's "Principia" had been written and published, yet the structure of the earth was unknown. A century ago the character and origin of the ground on which he trod and the formation of the rocks beneath his feet man did not know, though cosmical theories had been advanced by a few learned men; while the more extended knowledge which now enables us to give an incontrovertible account of man's abode was not possessed by any one, however learned.

Indeed, it is not too much to say that, while some other sciences were advancing by leaps and bounds, terrestrial knowledge had made no headway until Hutton's "Theory of the Earth" was published. But after that epoch-making event, notwithstanding even then much strong opposition, geology advanced by rapid strides. It enlisted the enthusiastic love and devotion of some very able men, the Geological Society was founded, as was also a Chair of Geology at each of our two great Universities, and Dr. William Buckland, afterwards Dean of Westminster, was appointed to be the first teacher of geology in the University of Oxford and the Rev. Adam Sedgwick to a similar position at Cambridge. The State recognised the substantial character and the utility of geological science by the creation of the Geological Survey of Great Britain and Ireland, and for half a century the truths revealed by geological investigation have been acknowledged and highly valued in every civilised country on the globe.

At the beginning of the last century, however, the almost universal belief was that the world was a recently created globe, so recently, indeed, as about 6,000 years ago. The same may be said of the general knowledge of the people of this country only half a century ago. Fifty years ago it was taught in every school that all time with which men had to do in the past commenced just 5,916 years ago. So perfectly satisfactory and indeed indisputable did this seem to be, that a "chronology" giving the date of the Creation of the World as 4000 B.C. was printed at the commencement of school text-books of history of the highest repute, without any note or explanation that it was on the authority of Archbishop Ussher. And coming to the present time, experience of popular knowledge, and even of the knowledge acquired at Public Schools and Universities, reveals the humiliating fact that the high antiquity of the earth stated by geologists is regarded with incredulity and the old date, "4004 B.C.," remains as a permanent acquirement of the mind. Indeed, a six-thousand-year-old world is the usual basis of much of what one hears in ordinary conversation, and of much of what one reads in the newspapers and popular literature of the day.

And yet our most renowned Universities, those “seminaries of sound learning” as the Church calls them, have for many years taught the high antiquity of the earth, the Geological Society has been established a hundred years, and, it may be added, there is to-day no teacher of repute that would deny the great conclusions of geology as to the formation and the gradual—very gradual—approximation of the exterior of the globe and its animal and vegetable organisms to the conditions that now fit the world to be the habitat of mankind. Not only is this so in our own country, but in the other great civilised nations of the world it is so also, and their State institutions for the dissemination of geological knowledge are well organised and equipped, and annually issue maps and reports that are equal to, and in some cases superior to, those of the United Kingdom. Even Spain, a country usually regarded as backward in education and educational facilities, produces geological maps of the highest value, and, as I have had the pleasure of finding, geologists of high attainments. On the American continent, Argentina has splendid national collections of the fossils of South America and evinces the highest appreciation of geological knowledge, while the United States sets an example to the whole world by its magnificent State publications to describe and illustrate the geology of North America. Notwithstanding this endorsement and acceptance of the conclusions of geology by the highest intellect of the civilised world, the bulk of our

British population have, with a seemingly loving fondness, retained the belief in a recent creation of a comparatively small universe, oblivious apparently of the higher and greater conception of the supreme Creative Power which is given by a universe illimitable in duration and extent.

This is so far-reaching in its results, and so mentally confining and so spiritually compressing in its individual consequences, that it is of national importance that its causes be inquired into and if possible removed. When looking for the causes of this lamentable halt of the English mind, we must come to the conclusion that the teachers of the people are primarily to blame. In our ordinary schools the great teachings of the rocks are altogether ignored, although those teachings would not only stock the youthful mind with knowledge both practically useful and theoretically informing, besides being a most agreeable and useful change from book-work, but also with thoughts and ideas that would elevate the mental standpoint, and so in every way improve that rising generation with which educationalists are so justifiably concerned. The great and absorbing attention—indeed, the enthusiasm—now given to sport, like "the loud laugh," bespeaks "the vacant mind," and it is to be feared that the usual teaching at our schools does not tend to fill the vacant mind with that knowledge which from its interest as well as from its gravity remains to fix the attention more on things of higher import than the customary frivolous occupations of the leisure of our youth and young men.

But, it may be asked, why do not those most influential teachers of the people, the religious instructors, take the utmost pains to disseminate a knowledge of the high antiquity of the globe and its relation to an illimitable universe? For surely nothing could so effectually elevate the general conception of the Creative Power, nor lead the youthful mind to the very foundation of all religion in the minds of young men and women—reverence and regard for that which is "without ourselves," as Matthew Arnold said, and which reverence is so lamentably lacking in great numbers of our present-day young people. It is, therefore, to be greatly regretted that the clergy, and the ministers of religion generally, instead of repeatedly calling the attention of their congregations to this most important matter, with very few exceptions quite ignore it, and placidly and complacently allow their people to continue in the cramping and belittling conceptions of the sixteenth century—conceptions of a small and, if not anthropomorphic, certainly, if the term may be used, anthropopsychic God.

The Universities of Oxford and Cambridge, although they have done much for the teaching of geological science to geological students, do not insist on even the most elementary part of this teaching being given to the candidates for the pass-degree, with the result that only a few undergraduates know anything of the teaching of the rocks, that the Public Schools in turn neglect this most essential instruction, and that the simplest yet the greatest conclusions of geology remain unknown to the great majority of the so-called educated, as well as of the uneducated, inhabitants of Great Britain. To students for the Church geology should certainly be taught, but, instead, it seems to be regarded as essential that teachers of religion should be highly instructed in ancient classical and ancient Oriental writings, written in the pre-scientific times of mythology and great superstition, but not at all necessary for them to know anything of the records of the rocks, which no one can deny to be the Word of God, written not in any mere human language, but in the Divine language of facts which remain truths through all time. Classical learning and ecclesiological theology should certainly be fostered, but the acquirement of some knowledge of natural operations should not be neglected. Let both receive the attention they deserve.

Sufficient has perhaps been here stated to support the contention that the age of the world is a subject that ought, in the interests of the nation, in the interests of education, and in the interests of religion, to be pressed upon the attention of the masses of the people and be taught by all instructors, whether secular or religious.

CHAPTER II

THE LARGER CHRONOLOGY—THREE PERIODS—MANKIND'S INDEBTEDNESS TO GEOLOGY

BEYOND the general knowledge of the great fact of the high antiquity of the globe, and as a consequence of the phases through which geological science has passed and the phase it has now reached, there has been a development of the desire of geologists to know, at least within maximum and minimum limits, the actual time in years that has elapsed since the earth first existed as an exteriorly solidified globe, or since, in Lord Kelvin's phrase, the establishment of the *consistentior status.* It may be said that this is chiefly, if not altogether, due to the general acceptance of the evolutionary phase of geology. Previously, from the reign of uniformitarianism, the age of the earth was regarded as too vast, too illimitable, for any approximate, or even maximum and minimum, estimate to be formed, and, indeed, whether it was 1,000 millions or 10,000 millions, or even 100,000 millions of years, did not appear to be of any practical importance. But when physics extended its survey to the investigation of the solar heat, the secular cooling of the globe, the retardation of rotation by tidal friction, and the figure resulting from spherical rotation, it was seen that terrestrial causation was of a distinctly limited character, and that there were data available on which might be founded an estimate within limits of its duration, of its beginning, and of its end. Recent advances in biological science have also taught a limitation of terrestrial time, and biology joined with physics in bringing about the present evolutionary phase of geology.

From this has sprung the recent increased interest of geologists and other students of science in the question of the age of the earth, and the extended attention it has lately received. So crystallised has this interest become that Lord Kelvin has declared that he would rather know the date of the *consistentior status* than that of the Norman Conquest. But while attempting to estimate the duration of the time since the first solidification of its exterior, we must remember that the existence of the globe did not then commence. That solidification was indeed only the commencement of a third distinct period of its existence The existence of this planet may be said to have extended through three periods, the first of which is hypothetical, the second consequential, and the third historical, since its history has been written in language both clear and unimpeachable, the universal language of the records of the rocks.

The First Period saw the aggregation of the matter of the earth; its fused and intensely heated condition; its assumption of the globular form; its revolution around a great overmastering attracting body, the sun; its rotation around a constant axis, and its consequent deviation from the spherical to the spheroidal figure; and, subsequently and finally, the loss of one-eightieth of its bulk by the separation by centrifugal force of its equatorial, exterior, protruding portion, with the resulting formation of the moon.

The Second Period saw the solidification of the exterior by cooling, by which the first permanently solid rocks of the globe were formed; the furrowing or wrinkling and local depressing of the surface by shrinkage; the cooling of the hot and heavy vaporous atmosphere, with the consequent condensation of the water-gas (H_2O); the gradual filling of the surface hollows with the water so condensed, and the consequent formation of the primæval seas and oceans of the globe; the commencement of the destruction of the first formed land by the continuous and heavy rain, highly charged with acids; and the transportation of the eroded material and its deposition beneath the waters of the first-formed seas. Thus would be accumulated vast thicknesses of sedimentary rocks, to be afterwards melted by interior heat or transformed in character by metamorphosing agencies.

The Third Period saw the commencement ot organic life, following on the establishment of the necessary atmospheric and land conditions. With variations of temperature between 32° and 212° F., winds would be produced, with evaporation and precipitation of water, that would give storms, and rain, and rivers, and so denudation, transportation, and deposition, and the formation of sedimentary rocks would be continued. The earlier of these rocks would also afterwards be largely metamorphosed, and any organic remains entombed in them obliterated; but they are the foundation-stones of the vast pile of stratified and fossiliferous rocks of later ages. This Third Period, therefore, witnessed the accumulation of the stratified rocks, and the innumerable generations of animals which have successively inhabited the globe, with the introduction of higher and higher forms, or organisms of greater and greater complexity; and witnessed, too, the production of those great physical features of mountains, valleys, and variously indented coast-lines which now diversify the land-areas of the globe. And along with all this animal life and these geological results there was the growth of plants: at first lowly cryptogamic organisms, and afterwards lordly forest trees and the vast variety of phanerogamic vegetation which now clothes and beautifies the surface, for this Period has seen all the geological and biological changes that have been in progress up to the present time.

It is the Third Period, the Period which still continues, and the Period to which it is usual to refer as geological time, that will now occupy our attention. Whatever may have been the length of the First and Second Periods, the Third Period we know has been one that is not to be measured by thousands, or even by ten-thousands, but by millions of years.

Various estimates founded on geological, physical, astronomical, and even on chemical data have been formed, but all agree in assigning a vast epoch, stated, as has been said, in millions of years.

Few things during the recent past have been more marked than the expansion of human conceptions of time. Not long ago, as has been previously pointed out, to all except a select few, a decade of millenniums included the whole of past time, while now, on the contrary, scientific knowledge teaches that a decade of millenniums is but a very minute portion of the time with which mankind has to do, for man is not only interested in the epoch during which the human race has existed, but he is also concerned with the whole of the period occupied with the production of the conditions suited for his life, welfare, and development. This knowledge teaches that man himself has been an inhabitant of the earth for a much longer period than had previously been supposed, and it teaches that previous to man's existence the globe had an immensely long history of changes and formative processes, the results of continuously working agencies and forces of nature. For this teaching it is necessary to resort to the records of the rocks, to those facts telling of the long past conditions of the earth which preceded the advent of man, and reveal the long continued processes of nature that produced the rocks that form the habitable lands of the globe. For the expansion of the conception of time, the world is therefore greatly indebted to geology, that very modern science of which Britain may be said to be the birthplace, since Dr. James Hutton, of Edinburgh, and William Smith, of Oxfordshire, have been called the Fathers of Modern Geology.

When condemning the mistakes of men of science, and criticising those conclusions which do not appear to be sufficiently supported by facts and sound reasoning, many critics are liable to overlook, or to forget, the greatness of the debt all mankind owes to science for those revelations that are now established truths, for the absolute and irrefutable knowledge so given to the world, and for those large general teachings that are as firmly established as it is possible for any conclusions to be—teachings that dominate, and must ever continue to dominate, the conceptions of the human mind throughout the future. Physics, astronomy, and biology have endorsed and confirmed the high antiquity of the earth, but it was geology that made the discovery, and to geology, consequently, the world is primarily indebted for all the far-reaching teaching of that great and pregnant revelation. But while giving full credit to geology for the revelation of the history of the formation of the rocks constituting the exterior of the globe, astronomy should be credited with having largely contributed to the expansion of the human conception of time. When the vast distances of the heavenly bodies were made known and the knowledge that light travels at a certain rate of speed was obtained, the age of the universe was seen to correspond with its illimitable extent.

Although the testimony of the rocks to the antiquity of the earth appears to us so clear and even conspicuous, it escaped the observation of nearly all the students of nature and philosophers of ancient and mediæval times, and was strenuously opposed by eminent thinkers who lived before the nineteenth century. And yet as early as the sixth century before Christ Pythagoras taught that solid land has been converted into sea, that sea has changed into land, that marine shells lie far distant from the deep, that valleys have been excavated by running water, and that floods have washed down hills into the sea. Aristotle and Strabo, too, had a conception of a large, continuing, and slowly changing world, and the latter plainly taught the upheaval and subsidence of not merely small insular lands but of great continental areas, and that it was the movement of lands that affected the sea, rather than that the movement of the sea affected the land.

In more recent times the famous painter, Leonardo da Vinci, who was also an engineer and a philosopher, the great Dane, Steno, and our countryman, Hooke, had perceptions of the truth, and saw clearly that fossils were real remains of living organisms entombed and preserved by natural agencies. Others might be mentioned, both of ancient and mediæval times, who had glimpses of the truth, but it was Dr. James Hutton who, in his "Theory of the Earth," first elucidated the great fact that the rocks forming the land on which we live were produced by natural and continuing agencies through enormous periods of time. With one bound did the Father of Modern Geology advance from the then prevalent catastrophism to extreme uniformitarianism, for he declared that terrestrial phenomena indicated "no vestige of a beginning, no trace of an end." This view is now no longer held, but it must be remembered that in Hutton's day there was not that extensive knowledge of the contents of the rocks which has so abundantly rewarded the labours of geological investigators during the last century.

Great as was the effect on the scientific world of "The Theory of the Earth," catastrophism or convulsionism, as it is also called, held the field during the early part of the nineteenth century, and it was not until Sir Charles Lyell published his famous work, "The Principles of Geology," that it received its deathblow, yet it still lingered for many years, it may perhaps be said almost to the present time.

Lyell's work enlisted the attention of men of science in all lands to the importance of geological science, and gained for the great principle of the interpretation of the past by the present the support of the most eminent of the scientific world.

Although the latest phase of geological science, the evolutionary, has displaced extreme uniformitarianism, Lyell's fundamental principle remains established, and his wonderful assemblage of descriptions of geological phenomena in all lands, and his masterly presentation of these facts, will always render "The Principles of Geology" the chief classic of the science.

To Herbert Spencer, Darwin, Huxley, and Lord Kelvin we owe that modification of uniformitarianism called evolutionism. Evolutionism does see a beginning and does foresee an end of terrestrial conditions, but it does not deny that geological phenomena are the result of forces and agencies of nature now operating, and, consequently, although evolutionism limits, it does not in any way affect the general conclusion of the vast antiquity of the earth.

CHAPTER III

PHYSICAL, ASTRONOMICAL, BIOLOGICAL, AND CHEMICO-GEOGRAPHICAL ESTIMATES OF TIME

It is the limitation of the age of the earth that has produced the present desire for some definite estimate of that age, and has thus given rise to various methods by which such an estimate may be arrived at. These may be described as Geological, Physical, Astronomical, Biological, and Chemical or Chemico-Geographical.

Of the results obtained by these methods, it may be said that the estimate from Physical data is the lowest (26 millions of years), that from Biological data is the highest (400 to 600 millions of years), and those from Geological data, Astronomical observations, and the Chemico-Geographical method are intermediate.

Sir Archibald Geikie's Geological estimate is 100 millions, Professor Sir George Darwin's Astronomical estimate is 56 millions, and Professor Joly's Chemico-Geographical estimate is 96 millions of years.

The Physical Estimate.—The Physical method was first presented to the world by Lord Kelvin, then Sir William Thompson, in 1868, and since that year it has been repeatedly brought forward up to the time of its author's address to the Victoria Institute in 1897. This method has, as it were, a triangular base, since it has three feet or supports. The first of these is the secular retardation of the earth's rotation by the tides and the permanence of the spheroidal figure of the globe since the solidification of the exterior. The second is the secular cooling of the planet, and the third foot is the expenditure of the sun's heat.

On these grounds it was at first concluded that the time since the solidification was not less than 40 millions and not more than 400 millions of years. Subsequently this estimate was reduced to a minimum of 20 millions and a maximum of 100 millions, and in his address of 1897 Lord Kelvin gives 26 millions of years as his estimate of the period during which life has been on the globe. This period has been further reduced by another eminent physicist, Professor Tait, to 10 millions of years.

It may be here mentioned that Professor Sir George Darwin, the distinguished son of an illustrious father, has shown that both Lord Kelvin's and Professor Tait's assumption of a permanency of the amount of deviation from spheroidicity since the solidification of the globe cannot be granted since even with a globe solid to the centre, by an infinite number of infinitesimal changes at the surface during an immense period of time, readjustment of form to that required by rotation may be effected.

Again, the second foot of Lord Kelvin's base is open to the objection that the assumption of increase of heat with depth below the surface at the rate of 1° F. for each 50 feet of descent cannot be granted either, for the British Association Report on Underground Temperatures only gave the average of the results obtained from actual workings, the majority of which were not in localities where underground temperatures were least likely to be abnormally high from local subterranean thermal conditions, and to obtain a true cosmic result, a minimum rather than an average increase of heat should be taken. In one place in our own islands the rate of increase with descent was found to be 1° F. in 92 feet, and in another 1° F. in 130 feet. In Bohemia it was 1° F. in 126 feet, and Professor Agassiz gives 1° F. in 223·7 feet in the Pre-Cambrian region of Lake Superior. But if only 1° F. in 90 feet be taken, the estimate would be raised, as Professor Sollas points out, to about 50 millions of years.

It has, besides, been objected, and by an eminent physicist, Professor Perry, that the conductivity of the interior masses of the globe may be greater than that of the exterior rocks, and probably is so from the greater proportion of metallic minerals, and that from their greater density the interior masses will certainly have greater thermal capacity.

The third foot of Lord Kelvin's base is open to the objection that we know little of the interior constitution of the sun, and that we are therefore ignorant as to whether there may not be some process by which the solar heat is maintained or fed or renewed. We have had recently, in the so-called "new star," *Nova Persei*, a reminder that accessions of heat and light by suns may be received at any period of their existence, and if in this case the accession was sudden and great, he would be bold indeed who would venture to say that an accession of heat and light might not be given slowly and to a small extent. Professor Sir George Darwin, it may be added, allows 500 millions of years as the limit of the sun's age without any fresh accession of heat.

While, therefore, the highest respect ought to be paid to the conclusions of so distinguished an authority as Lord Kelvin, it would appear that it is by no means conclusive that, even from physical evidence alone, the age of the earth as a habitable globe ought to be limited to Professor Tait's 10 millions, or even to Lord Kelvin's 26 millions of years.

The Biological Estimate.—But if the estimate from physics greatly reduces the geological estimate requiring 100 millions of years, Biology asks for much more time.

At the Liverpool Meeting of the British Association in 1896, Professor Paulton, the President of the

Zoological Section, devoted his Presidential Address to the question of the age of the earth, and then gave the opinion that 450 millions of years would be required for the evolution of animal life, such as it is at present on the globe, from the first living matter. Professor Paulton supports his contention by a formidable array of zoological facts adduced to show that higher forms change more rapidly than lower, and that from the slowness of change in comparatively high forms which appear so low down in the geological series as the Lower Palæozoic, we must conclude that a vastly greater amount of time has been required for the development of these forms, which in some cases have scarcely shown any change from the Cambrian Period to the present.

Amongst his illustrations of the small amount of change given by the lapse of the, admitted by all, enormous amount of time since the Palæozoic epoch—or, as he expresses it, "the divergence and specialisation from Palæozoic insects to the present are amazingly small in amount"—Professor Paulton cites the cases of the common cockroach and Peripatus. Of the former he says: "The Carboniferous cockroaches, Blattidæ, possessed ovipositors, and probably laid their eggs one at a time, while ours are either viviparous or lay their eggs in a capsule." Of Peripatus, which is now living but has not been found fossil, Professor Paulton says: "Peripatus has come down, with but little change, from a time, on a moderate estimate, at least twice as remote, and probably many times as remote, as the earliest known Cambrian fossil." That this interesting genus has not been found fossil is a striking example of the imperfection of the geological record. Another is that although 32 species of Myriapods have been found in Carboniferous strata, none have been discovered in any newer rocks until the Oligocene Tertiary deposits are reached. It may perhaps be added that Trigonia, which is a most conspicuous genus of Lamellibranchiata in Secondary rocks, has not been found in Tertiary strata, although it is now a well-known living genus. So greatly developed was the highly organised class Hexapoda, or Insects, in Palæozoic times, that no less than 42 genera and 101 species have been discovered in the Carboniferous rocks of one locality, Commentry, in Central France. The little advance in insect structure that has taken place since Carboniferous times is especially striking, for "all the great questions of metamorphosis, and of the structures peculiar to insects, appear to have been very much in the position in which they appear to-day." The argument is summarised as follows: "Undoubtedly a study of all the available evidence points to the conclusion that in the lower grade, sub-grades, and Phyla of the Animal Kingdom, evolution has been extremely slow as compared with that in the higher. All the five cœlomate Phyla which occur fossil appear low down in the Palæozoic rocks in the Silurian or Cambrian strata. The earliest vertebrates to appear are, in fact, very advanced members of the Phylum, and, from the point of view of anatomy, much nearer to man than to Amphioxus. Evidences of marked advance are to be found alone in the most advanced groups of the latest highest products—the Phyla formed by the last of these divisions." Professor Paulton's argument may be briefly stated thus: With complexity of structure there is increased rapidity of change, and hence the time required for the production of the Cambrian fauna, which includes the high forms of Crustacea and Mollusca, must have been much greater than the time required for the development of these forms into the higher Mammalia of the Pleistocene and present times. From these considerations it is concluded "that the whole period in which the rocks were laid down must be multiplied several times for this later history alone. The period thus obtained requires to be again increased, and perhaps doubled, for the earlier history." This would give at a moderate computation from 400 to 600 millions of years for the age of the earth, or rather the time that has elapsed since the cooled solidified exterior of the planet gave the first possibility of animal life on the globe.

The Astronomical Estimate.—The Astronomical method of calculation, or rather estimation, which we owe to Professor Sir George Darwin, is founded on that secular acceleration of the movement of the moon of 12″ per century discovered by Halley in 1693. This acceleration is partly due to a slow lengthening of the sidereal day, from the secular retardation of the rotation of the earth on its axis, consequent upon the frictional action of the tides. Again, on the hypothesis that the moon was formed by the separation from the earth of one-eightieth of its bulk when in a fluid state, the result of the action of centrifugal force and the sun's tidal influence on the fluid globe, the satellite must have continuously receded from its primary until it reached its present distance of 59 semi-diameters or radii of the earth. Making use of the data supplied by these phenomena, Professor Darwin calculated back to the time when the moon was distant only nine terrestrial radii from the earth. It was thus found that such a position of the moon must have been 56 million years ago. It will be obvious that a result of this character is a minimum one, since no account is taken of the time that elapsed between the detachment of the matter of the moon and the attainment by the satellite of the distance from the earth of nine terrestrial radii.

The Chemico-Geographical Estimate.—The Chemico-geographical basis of estimation, as I have ventured to call it, is the most recent, and was first brought before the Royal Dublin Society in 1900, and afterwards before the British Association, by Professor Joly. It is an extremely interesting and very ingenious method of arriving at the wished-for result. This method is based on the amount of sodium now in the sea waters in combination with chlorine, giving the salt of sea-water, and the amount of sodium taken annually to the sea by the rivers of the globe. This assumes, of course, that the water of the first formed seas of the globe, the result of the condensation of the water-gas in the original terrestrial atmosphere, was non-saline, or "fresh," and that the present saltness of sea-water is due to the sodium taken from the rocks of the globe by the decomposition of their component minerals, combining with chlorine, and so forming the chloride of sodium, or what is called "common salt." Professor Joly estimates the amount of salt in the waters of the globe at present at $36{,}566 \times 10^{12}$ tonnes (metric tons), which will give, as the amount of sodium in the sea-water of the globe, $15{,}611 \times 10^{12}$ tonnes. From Sir John Murray's estimate of the volume of river-water annually discharged into the sea, and from the amount of sodium salts in the waters of nineteen representative rivers, "many of them principal rivers of the globe," the quantity of sodium annually taken to the sea from the land is estimated at $15{,}976 \times 10^{4}$ tonnes. Some small corrections are made to allow for the amount of sodium obtained from the rocks of the sea-bottom by the first condensed water, and the salt taken back to the land, but the general result is that the amount of the sodium now annually taken to the sea is the $\frac{1}{96}$-millionth part of the amount at present in the seas and oceans of the globe. Professor Sollas has pointed out some sources of error in these estimates, but he admits that they do not invalidate the main conclusion. It is obvious from their mineral composition that igneous rocks will yield a far larger amount of sodium than ordinary sedimentary or so-called aqueous rocks, and that areas formed by igneous rocks are not as a rule drained by large rivers. On this point Professor Sollas may be reminded that two of the greatest rivers, and two included in those selected, carry to the sea the materials taken from regions of igneous rocks—the Nile from Abyssinia, and the Amazon from the Andean volcanic regions of Peru and Ecuador.

The conclusion of Professor Joly, from his novel method of estimation, is, as will have been gathered, that 96 millions of years have elapsed since the original water substance of the first terrestrial atmosphere, the first formed H_2O, was condensed into liquid water and so formed the primæval seas of the globe.

CHAPTER IV

THE GEOLOGICAL ESTIMATE

The geological evidence for the high antiquity of the earth is based on stratigraphical and palæontological facts, which in themselves and in their general significance admit of no dispute, for they may be seen and appreciated of all men. They are simple, decided, and conspicuous.

The first and chief stratigraphical fact is the vast thickness and vast extent of the sedimentary rocks. The latest estimate of the aggregate thickness of the rocks that have been formed by successive accumulations of solid material under water gives 265,000 feet, or about 50 miles. This thickness of 265,000 feet, it should be remembered, is nine times the height of the loftiest peak of the Himalayas above the level of the sea. This enormous thickness of solid rock has been accumulated by the ordinary force of gravitation, which has assorted the solid material taken to the sea, giving coarser beds in one place and finer beds in another, where the more tranquil conditions of deeper water allowed of the falling and settlement of minute mineral particles. Thus we find pebble-beds, conglomerates, grits and coarse sandstones, fine sands and sandstones, and finer clays, shales, and slates. With these there are limestones, some of great thickness, formed by the accumulation of solid carbonate of lime extracted from the water of seas and lakes by the physiological power of animal life or by chemical precipitation. These are all slow, very slow, processes of nature, and hence no other conclusion can be arrived at than that a vast period of time has been required for the accumulation, layer after layer, of such a prodigious thickness of solid matter.

But not only are the sedimentary rocks of vast aggregate thickness, but they are of vast extent also, for it is found that nearly all the land areas of the globe consist of these rocks, the areas formed by igneous rocks forming altogether a very small part of the surface of the land. In the British Islands there are only a few irregular patches of very limited extent, a larger number of long narrow "dykes" or "sills," and a number of mere spots of non-sedimentary or igneous rock. Altogether they do not form the one-hundredth part of the whole land area of these islands, and although there are in other countries much larger areas of igneous rock, as in Iceland, Abyssinia, and India, yet, taking the whole land area of the globe, there is certainly not a larger proportion of non-sedimentary rock than there is in the British Islands. We thus see that the enormously thick masses of sedimentary rocks have not been the result of accumulation in one or two small seas only, but, on the contrary, the material has been spread over areas equal in the aggregate to 99 per cent. of the present land of the globe. If now the land-area of the globe be taken at 52 million square miles, 99 per cent. of this will be 51,480,000 square miles, and if an average thickness of 12·5 miles be taken, or about only a quarter of the aggregate maximum thickness, the result will be 643,500,000 cubic miles of solid rock accumulated by the slow deposition of moderately small, small, and very minute particles. That a quarter of the maximum thickness of the sedimentary rocks is not too much to be taken as a mean thickness will be, perhaps, apparent from the following facts.

The Pre-Cambrian sedimentary rocks have a maximum thickness estimated at 80,000 feet, and these rocks, where they are at the surface, occupy an area in Canada alone of 2,000,000 square miles, and they are at the surface also and of great thickness in the North-west of Scotland, in Norway, and in many other parts of the Europeo-Asiatic continental area. The Lower Palæozoic rocks, including the Cambrian, Ordovician, and Silurian, may be taken at 50,000 feet of maximum thickness. In certain regions, it is true, some of these rocks are much reduced in stratigraphical importance, as in Sweden, but in many other regions they approach their maximum thickness throughout very wide areas, and these so distantly separated as the British Islands, Spain, South Africa, North America, and Australia.

The Newer Palæozoic rocks, including the

Devonian and Old Red Sandstone, the Carboniferous and the Permian, with an aggregate maximum thickness of about 60,000 feet, present similar phenomena. The Devonian rocks of Great Britain range from 16,000 feet in Caithness to 10,000 feet in Herefordshire, and to 3,000 feet in some parts of Scotland, while in the Franco-Belgic area they are 10,000 feet, in North America 11,000 feet, and 10,000 feet in Australia. The Carboniferous rocks attain in Nova Scotia a thickness of from 15,000 to 16,000 feet, and on this side of the Atlantic the Coal Measures alone are in South Wales 12,000 feet thick, and in Lancashire 8,000 feet, where another division of these rocks, the Millstone Grit, has a maximum thickness of over 5,000 feet. One of the Carboniferous formations, the Carboniferous Limestone at the splendid section near Bristol, may be seen to be fully 3,000 feet in thickness of compact limestone, the whole of the material of which has been obtained by myriads of generations of marine animals from the water of an ancient sea. In Germany the Coal Measures are 20,000 feet thick. The Carboniferous rocks altogether occupy in the British Islands very large areas, forming as they do, besides many smaller areas, the greater part of the North of England, a large part of Central Scotland and of South Wales, and nearly the whole of the midland parts of Ireland. In North America there are 200,000 square miles of Coal Measures at the surface, in Russia 24,000 square miles, and in China many thousands of square miles. Carboniferous rocks in great thickness are in the Southern Hemisphere, in South Africa and Australia, and in the far North in Spitzbergen, while France, Belgium, Germany, and Spain each have large areas. There is positive evidence, too, of former most extensive areas of Carboniferous rocks with, alas, valuable seams of coal which have been swept away and destroyed by denudation, as in Ireland, Lancashire, Yorkshire, Durham and Cumberland, Somersetshire and Gloucestershire, in all of which areas in our own islands the Carboniferous rocks have once been much thicker than now. The Permian rocks have in this country a thickness of only about 2,000 to 3,000 feet, and do not now form a very large portion of the surface; but on the continent of Europe they constitute by far the largest part of European Russia, where they attain a thickness of 12,000 feet, and in India they are 10,000 feet thick. They also appear in Australia and in Africa, where they have 4,000 feet of thickness.

The Secondary rocks, taken altogether, do not rival the Palæozoic in thickness, and yet they are very considerable deposits in vertical dimension, while their horizontal extension is enormously great. In England and in Germany the Trias attains 5,000 feet, and in the region of the Pacific Slope of North America 15,000 feet of thickness. It is wide-spread in Europe, and in Asia extends through Asia Minor, Syria, Kashmir, the Salt Range of the Punjaub to Western Thibet. In South Africa, as the Karroo formation, it forms a very large area, and in Australia, New Zealand, and, again to the North, in Spitzbergen, there are Triassic rocks. The Jurassic rocks have in England a total thickness of about 4,500 feet, in the Alps 6,000 feet, and in India 6,300 feet. In France they are largely developed; in Russia they form a larger area than in any other part of Europe; and they are represented in both North and South America as far South as the Argentine Republic. Remnants of the Jurassic rocks in the Hebrides and in Sutherlandshire tell of their former extension over the whole of Scotland, another reminder that much of the rock masses that have been formed has subsequently been destroyed.

When the Cretaceous rocks are considered, we are astonished at their world-wide extension. As is well known, they extend in England from Dorsetshire to Flamborough Head, and to Dover and Beachy Head on the southern coast; while in Ireland they are in the North and in Scotland there are remnants. On the continent of Europe they are at the surface in France, Germany, Denmark, Scandinavia, Russia, Poland, Bohemia, Italy, Spain, Portugal, Greece, and Turkey. They are in the North of Africa; in India they form over 200,000 square miles, and far to the North-west, a vast area in North America, extending to the Arctic Circle, and another vast area far to the South-east in Australia, and still farther South they are 8,000 feet thick in New Zealand. In North America the Cretaceous rocks are from 11,000 to 13,000 feet thick, and in India 6,000 feet. In this country they have an aggregate thickness of about 4,000 feet, including the Chalk of upwards of 1,000 feet, a pure limestone consisting altogether of the microscopic shells of marine foraminifera. Vast as is this extension, it is but what remains after great destruction, as is exemplified, like the destruction of Jurassic rocks, by a remnant in the North of Scotland.

The Tertiary rocks have been estimated to have a total aggregate maximum thickness of 38,000 feet, though of very varied importance. In England the Eocenes are altogether only about 800 feet thick, but they include in the continental areas of the Eastern Hemisphere the great Nummulitic limestone that extends through Southern Europe, Asia Minor, Persia, and India to China and even to Japan. In Southern France the Eocenes are 3,000 feet thick, in Italy 5,500 feet, in India perhaps 10,000 feet, and in North America as much as 12,000 feet. The Oligocenes, with a maximum thickness in England of only about 800 feet, form rocks in Switzerland 9,000 feet thick, and in Italy they attain a thickness of nearly 12,000 feet. Although we have no rocks in this country of undoubted Miocene age, the Miocenes of the Mediterranean Basin are of great importance, and form large areas in Southern Europe. In Italy they are estimated to be nearly 6,000 feet thick, and in India they may probably be 8,000 feet. In the Southern Hemisphere there are Miocene rocks in Australia and New Zealand, and in Arctic regions in Greenland

and Spitzbergen. In the United States, both in the Eastern States and in the Western, there are beds of Miocene age attaining a thickness of 2,000 feet. The newest of the Tertiaries, the Pliocene deposits, also attain a much greater importance abroad than they do in the British Islands. Here they may have a total thickness of 300 feet, while in Sicily they are 2,000 feet thick, and in India the great thickness of from 12,000 to 15,000 feet. They are likewise widely extended, since they occur in great development in Austria and in Southern Europe, in Greece at Pikermi and Samos, in North America, and in Australia and New Zealand.

Besides the existing rocks, those that have been removed by denudation have also to be taken into account. It has been shown from one or two examples that immense portions of completed formations have been destroyed. Over vast areas, indeed, where older rocks now occupy the surface, newer rocks have been deposited and subsequently removed by denudation. Again, in the geological series of the stratified rocks there are some very decided breaks where great unconformability occurs, each break or lacuna indicating a great lapse of time without a formation corresponding to it to be found. Here also there is evidence of destruction on a great scale of portions at least of once deposited formations, for remaining portions may yet be found.

From these stratigraphical data it is conclusively established that the sedimentary rocks maintain their immensely thick character throughout most extensive regions, and that vast masses of such rocks have been destroyed. It will seem to many, therefore, that the total amount of the material that has been deposited must be fully half of the maximum thickness of the existing sedimentary rocks. In taking a fourth part only there will consequently be no danger of overestimating the amount of material that has been deposited since the formation of the sedimentary rocks commenced. This gives, as has been said, 643,500,000 cubic miles.

All this material has been taken from land areas of the globe by the slow destruction of the rocks, including many of the hardest and most enduring character. It is possible to estimate the rate at which this destruction of the surface is proceeding by ascertaining the amount of detrital matter carried to the sea by rivers annually, and dividing this amount by the area of the river-basins. Applying this method to the great river-basins of the globe, it has been found by Sir Archibald Geikie that there is an average destruction of the land surface of $\frac{1}{2400}$ foot per annum. If now we take 12½ miles thickness of rocks with an area equal to the land of the globe, and assume that the land area was even as great in Palæozoic and Secondary times as at present, we find that 59,400 feet of surface rock has been removed, which would require 142,560,000 years. Thus a probable minimum estimate of the age of the world, or rather of the age of the oldest sedimentary rocks, is arrived at from geological data.

CHAPTER V

THE GEOLOGICAL ESTIMATE—*continued*

It may be asked, however, Do the geological formations at all correspond in character with present-day sedimentary accumulations? The answer is that they do correspond, and exactly correspond. The sedimentary rocks consist of either unaltered, or altered by present acting geological agencies, shingle beds, gravel beds, sands, clays, and accumulations of carbonate of lime. These are precisely the kind of deposits that are at present being formed beneath the waters of the globe, by the removal of material from the surface-rocks and its deposition and accumulation at the bottoms of seas, estuaries, and lakes. Thus there is conclusive evidence that these rocks have been produced by the same agencies and forces of nature that are now acting.

And even if this evidence were not sufficiently cogent, Palæontology steps in and confirms it by showing to us the embedded fossil forms which are obviously the enduring parts of animal and vegetable organisms such as live on the globe at the present time, and which have died and been entombed in the slowly accumulating sediment of previous epochs of the world's history.

But, it may be said, natural forces the same in kind as those acting now may have been very different in degree. They may have acted in Palæozoic and Secondary times with much greater power and intensity than at present, and hence the rate of erosion and the rate of deposition would be very much more rapid, and consequently estimates formed on the rate of present action are altogether misleading and worthless. This is a perfectly allowable and fair objection. But even were it valid and proved it would only have the effect of diminishing the time required for the acccumulation of 50 miles' thickness of rocks. It would not suffice to disprove the main and essential conclusion of geology, that of the high antiquity of the globe, and that an enormous amount of time, certainly millions instead of thousands of years, had been occupied in the formation of the present surface of the earth.

To the objection, however, it may be replied that the records of the rocks do not tell of any change in the intensity of natural forces since the Cambrian, or even since the Pre-Cambrian period. The rocks speak to us very plainly and very copiously, and yet they have never told any one of greater intensity of natural forces in the past than at the present time. On the contrary, they speak most eloquently and most fully of the forces of nature being in the far geological past not only the same in kind but the same in degree as those now geologically acting on the solid structure of the globe.

In the Pre-Cambrian rocks there are conglomerates with pebbles smoothly rounded by the action of the sea waves, just as we see going on to-day on our own coasts. Those rocks, too, comprise grits and sandstones of great thickness, formed by the accumulation of particles or grains of quartz on a sea-shore, which must have been the result of long-continued land erosion of hard rocks, just as at present. All this implies rain and rivers, atmospheric and marine conditions quite similar to those now existing. There are, besides, ripple marks on sandstones in these old rocks, telling of the rise and fall of tides leaving bare sandy shores with the ebb, amenable to the well-known action of advancing tidal waters. "One of the very oldest formations of Western Europe, the Torridon sandstone of North-West Scotland," Sir Archibald Geikie says, "presents us with a picture of long-continued sedimentation, such as may be seen in progress now round the shores of many a mountain-girdled lake. In that venerable deposit the enclosed pebbles are not mere angular blocks and chips, swept by a sudden flood or destructive tide from off the surface of the land, and huddled together in confused heaps over the floor of the sea. They have been rounded and polished by the quiet operation of running water, as stones are rounded and polished now in the channels of brooks or on the shores of lake and sea. They have been laid gently down above each other, layer over layer, with fine sand sifted in between them. So tranquil were the waters in which these sediments accumulated that their gentle currents and oscillations sufficed to ripple the sandy floor, to arrange the sediment in laminæ of current bedding, and to separate the grains of sand according to their relative densities."[1] In the Cambrian rocks of Carnarvonshire at Bethesda, Nantlle, and Llanberis, we see great beds of slate of so fine a texture that their homogeneity is such that they split with the most perfect regularity, so perfect, indeed, that plates of not more than $\frac{1}{16}$ inch thick may be cleaved of a length of three or four feet. This tells most certainly of the original clay being uniformly composed of the finest particles of kaolin that had for a long period of time most tranquil sea-water to sink through. Again, in these ancient rocks there are sun-cracks and rain-pittings, silently but eloquently telling of sunshine and shower in Cambrian times, just as at present, and even indicating the direction of the wind. All lithological data, it may be comprehensively said, unmistakeably prove an entire similarity of Palæozoic agencies, both in kind and degree, to those now geologically affecting the solid exterior of the globe.

But what is the Palæontological evidence? Surely

[1] Geikie, "Textbook of Geology," p. 76.

the remains of the animals and plants of Palæozoic and Secondary times would indicate more powerful and violent agencies when these animals and plants were living organisms, if such agencies had then been acting. Intensity of heat and cold, deluging rainfalls, impetuous torrential rivers, destructive air currents, sweeping winds, and supra-cyclonic storms, rapid and all-powerful oceanic currents, gigantic seismic sea waves, and rock-shattering breakers, would surely have left their mark on the organisms subjected to their dominating power.

The testimony of fossils is, however, entirely at one with the testimony of the lithological characters of the rocks, and in no case do they tell of different inorganic conditions from those now prevailing. In the earliest strata preserving fossils there are remains of crustaceans which, though differing generically, are similar generally to living forms, and these trilobites had shells and antennæ similar to those of present crustacea, and compound eyes similar to those of the crabs and limuli of present seas, indicating the similar general character of the sea water and its composition, temperature, and transparency. Moreover, the easily broken shells are found entire and in some cases even with the delicate antennæ still connected. The lingulæ, too, of Lower Cambrian age are almost identical with those now living, the shells no stronger and the foramen no larger, and therefore the byssus by which a brachiopod attaches itself to the rocks was no thicker. The antennæ of trilobites of Rome, New York, moreover, show that tranquil conditions extended over the globe. Such facts as these could not have been found had the Cambrian seas been subjected to great rushing waves or more violent storms than those of to-day. All tells of as much tranquillity of marine conditions as now exists.

There is clear evidence, too, of the land conditions being similar to the present. Trees and smaller plants of Palæozoic times were no stronger than those growing now, neither in stem nor roots; the fronds and frondlets of ferns were identical in character with those of our English woods and commons and Devonshire lanes. And then the insects, what do they tell of their environment? Exactly the same story. The Carboniferous insects that flitted from tree to tree of the forests of the Coal Measure period, as now in the forests of the Amazon, had such a breadth of wing as suited only generally calm and sheltered conditions, for had there been those constant violent storms which have been imagined, such insects would have been impossible. A remarkable discovery of fossil insects in the Carboniferous rocks of France tells us that in Palæozoic times there were dragon-flies with a spread of wing of upwards of a foot, a valuable witness to the calm of the great Carboniferous forests. At present Madeira beetles are often wingless and the insects of the Kerguelen Islands are always wingless, the effect of the stormy climate.

It is true that in some few cases there is evidence of somewhat rapid deposition, but this is merely in accordance with what is happening now, and does not at all show more rapid denudation. Where a large area is drained into a small one, as a lake or landlocked sea, there will be necessarily more rapid deposition and a quicker accumulation. These instances consequently only indicate exceptional and very local and limited conditions that do not affect general conclusions.

Nor do the larger features of the rocks indicate greater earth movements. The foldings which are so great in Palæozoic rocks are due to time rather than to greater forces, for these foldings are paralleled in kind in newer rocks, even in the Tertiaries, as may be seen so near as the Isle of Wight. The upheavals and compressions which have produced these foldings have been as great, if not greater, in Tertiary as in Palæozoic times, for we have no evidence of anything nearly so great as the elevations of the Alps and the Himalayas, the former of which was Post-Eocene and the latter Post-Pliocene. The great lava outpourings of the Deccan in India, Abyssinia, the North of Ireland, and other regions, were not in Palæozoic but in comparatively late geological times. The Glacial epoch, again, is one of the latest geological periods, only yesterday, as it were, compared with Palæozoic or even with Mesozoic times.

No evidence whatever has by any one been adduced to prove that the destroying or the transporting action of water was greater, the power of the winds was stronger, the decomposing force of chemical action was more potent, that marine waves were greater or more violent, that the internal heat of the globe, whether plutonic or volcanic, was more destructive or constructive, in Palæozoic times than at the present day. Everything that has been observed, whether stratigraphical, lithological, or palæontological, most clearly and conclusively shows that we have no reason whatever for concluding that since early geological times, at least, the terrestrial forces of nature have acted with greater intensity than at present, except, possibly, temporarily and locally.

These facts and considerations quite justify the conclusion that the land of Palæozoic and Secondary times was denuded at approximately the same rate as now, or, perhaps, it would be more correct to say not more rapidly than now, for erosion and removal of material might well have been less rapid than at present, since the land would in early geological times have a surface with a smaller proportion of the softer rocks than at present.

Geological evidence gives, therefore, according to this estimate, it would seem, a minimum of 140 millions of years as the time that has elapsed since the formation of the earliest known sedimentary rocks.

At the Edinburgh Meeting of the British Association in 1892, Sir Archibald Geikie, the President for that year, was satisfied with 100 millions of years, but he did not give the details of his estimate, contenting himself with a statement of general considerations.

Previously, Dr. Haughton computed the time at 200 millions of years, but he assumed the area of deposition to be the entire marine area of the globe, or three times the area of the land from which the material of the sedimentary rocks was derived, assuming the land and sea areas to have been similar in extent to the present. This great area of deposition cannot be granted, for although there is undoubtedly some deposition going on in the deepest seas, the accumulation on the floors of mid-ocean is so infinitesimal that it ought in this matter to be disregarded. The known extent of the sedimentary rocks is, I venture to think, a safer basis for estimating the area of past deposition. From this cause Dr. Haughton's estimate would appear to be too great, but on the other hand, he, while protesting against it, assumed the rate of deposition to be ten times more rapid than at present. The endeavour here has been to show that there is no reason to assume any more rapid rate of rock formation than the rate of the present epoch.

At the meeting of the British Association at Bradford in 1890, Professor Sollas, President of the Geological Section, made the age of the earth the subject of his Presidential Address, in which he allowed a deposition of one foot in a century of past time, and on this basis reduced Sir Archibald Geikie's 100 millions of years to 26½ millions from geological evidence, or to the same term as that given by Lord Kelvin from physical evidence. Professor Sollas founded his estimate of the rate of deposition on the area of deposition of the solid matter brought into the Gulf of Mexico compared with the area of North America from which that matter is taken and transported by the Mississippi and other rivers. But is not this an example of what has been here already referred to, namely, a very large area drained into the more limited area of a landlocked sea? Regarding the grounds here taken, namely, the extent of the stratified rocks and their great development in vertical thickness in widely separated and very extensive regions, as the most substantial basis for a conclusion as to the area of deposition in the past, Professor Sollas's grounds, and consequently his estimate, seem to be inadmissible.

The estimate by Sir Archibald Geikie of 100 millions of years, approximating as it does to what is a fair deduction from what seem to be the only reliable geological grounds, may perhaps be regarded as the Geological Estimate. But although from deference to the conclusion of so distinguished a geologist as the late Director-General of the Geological Survey of Great Britain this may be admitted, I yet venture to feel some confidence in the estimate of 140 millions of years as that of the minimum age of the first-formed sedimentary rocks.

It may perhaps be justly contended, quite consistently with all the great respect that is due to physical investigations and to biological research, that the bases of the estimates of the age of the earth by both physicists and biologists are more assumptive, more open to dispute, less clearly established facts, less substantial, and therefore more uncertain and less reliable, than are the grounds on which are founded the estimates of geologists.

Taking 26 millions of years as the Physical Estimate, 450 millions as the Biological Estimate, and 100 millions as the Geological Estimate, we find the last named occupying an intermediate place, and if it be true that both safety and wisdom are between extremes, geologists may be well content with their conclusion, especially when they find that they are supported by the physics and mathematics of Professor Perry, the astronomy of Professor Sir George Darwin, and the chemistry and geography of Professor Joly. On all grounds, therefore, 100 millions of years may, perhaps, be accepted as the minimum age of the world.

CHAPTER VI

EARLY CLIMATAL CONDITIONS

In the preceding chapter statements were made respecting the climatal and general inorganic conditions that obtained during the times when the material of the older sedimentary rocks was being deposited, with brief references to the grounds for those statements. As this is a most important and indeed an essential part of the basis of the geological conclusion of the great antiquity of the earth, it may be well to give here a rather fuller statement both of the deductions, and of the reasons for these deductions, which follow from the close observation of stratigraphical and palæontological facts.

There is a widely spread impression that the state of the surface of the earth and the prevailing climatal and atmospheric conditions of Pre-Quaternary geological periods were quite unlike those that now exist, so much so, indeed, as to be altogether unfitted for the human occupation of the planet. The vast number of extinct organic forms revealed by palæontological investigation, and the great divergence of many from those now living, as well as the late coming in of new species, have largely contributed to produce this belief; but, perhaps, it has been most encouraged by the fact of the vegetable origin of coal, since it has been thought necessary by some writers to assume such atmospheric and climatal conditions for the production of the Carboniferous flora as would be quite inimical to the existence of man. And yet the records of the rocks conclusively establish the great fact, that not only in Tertiary and Secondary times, but also in Palæozoic times—indeed, in the earliest Palæozoic times—general inorganic conditions were very similar to those of to-day.

It has been well said by a recent writer on extinct animals, when referring to distant geological periods: "Flesh and blood were then what they are now, and fulfilled the same functions. Bones grew then as they grow nowadays. To those bones were attached muscles, which expanded and contracted just as muscles do now. Wings were used for flying, fins and paddles for swimming, legs for walking, teeth for masticating food, just as they are now. In fact, these primitive inhabitants of the antique world, however different in bodily shape from those we see around us now, lived under the same universal laws of physiology as we ourselves do."[1] To this it may be added that these animals of the past lived, too, under the same general inorganic conditions as those in which we have our being.

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[1] The Rev. H. N. Hutchinson, "Creatures of Other Days," p. 2.

But this conclusion, most momentous and far-reaching though it be, seems strangely overlooked by some popular writers on geology. It may, therefore, be useful to briefly emphasise the undoubted teaching of the facts presented by a study of the Cambrian rocks and their fossils. As the Cambrian rocks are the lowest and therefore the oldest of the Palæozoic deposits and contain the earliest distinct organic remains yet found, the climatal conditions existing at the time when these remains were parts of living organisms will conclusively show the general inorganic conditions prevailing on the globe throughout geological time. The facts presented by these rocks, which reveal the inorganic conditions of early Palæozoic times, are some petrological and some palæontological.

The Cambrian rocks are not only of great thickness, but they form extensive areas both numerous and widely dispersed. In the British Islands they are conspicuous in Wales, whence they take their name, in Shropshire, Cumberland, Scotland, Ireland, and the Isle of Man; and on the continent of Europe we find them in France, Belgium, Germany, Bohemia, and Spain, and far North in Sweden and Norway. In the Western continent they form large areas in Canada, Nova Scotia, and the United States; and when we turn to the East we see these ancient rocks in far Cathay, for the Sinisian formation of China was shown by Richthofen to be of Cambrian age.

These accumulations of marine sediment are of very diverse character, presenting different lithological aspects in different areas, and consisting, even in the same area, of beds of greatly differing rocks. There are masses of sandstones, compacted and cemented aggregations of grains of quartz derived from the destruction of still older quartzose rocks, and there are also beds of conglomerates made up of pebbles, every one of which has been a water-rolled angular hard-rock fragment. There are, too, great accumulations of argillaceous matter, consisting altogether of materials derived from the decomposition of the felspar of granites or other felspathic rocks, and there are, moreover, in America, calcareous rocks, the material of which is the same as that forming those newer limestones which have obviously been the result of organic action. Volcanic rocks, in addition, are not wanting to furnish further evidence of what were the cosmic conditions of the globe in the Cambrian epoch. And over and above all this, there are markings on Cambrian sandstones identical in character with those now produced by waves and ripples on sheltered shores and shallow-water bottoms, as well as—and these are very significant—cracks and pittings, only ascribable to the action of the sun and rain.

Such are, briefly stated, the main petrological facts of the Cambrian rocks, and from these facts the following conclusions may be drawn:—

Since the whole of the material of which these rocks of great thickness and of diverse mineral character consist has been accumulated by the deposition of derived matter on sea-bottoms, exactly as marine sediments are now being accumulated, it follows that those agencies of nature, which are the controlling forces of the physical cosmos, were acting in the same way as at present. Not only do we see that the matter of the globe was the same in its chemical combinations and states of aggregation as now, but that the bulk of the water of the globe was in a liquid state, and that therefore the temperature over the greater part of the earth was, as at present, between 32° and 212° F.

The derivation of the material of the sediments required the erosion of land surfaces by water agency, requiring rain, which again required the atmosphere to be charged with varying amounts of water-vapour and water-gas, increased at one time by evaporation and at another time diminished by condensation. Thus there was rain that formed streams and rivers on the land, that wore down and destroyed rocks, the detritus of which was transported to the sea, in all respects exactly as at present. Thus, too, there were alternations of temperature to produce alternate evaporation and condensation, and those alternations were confined for the most part within very moderate limits as now. Clouds, too, would form, wax and wane, and with varying densities of aggregation of the watery particles assume those beautiful forms we know so well, and float at various elevations in the atmosphere; and when these clouds broke or dissolved, blue skies and bright sunshine would alternate with shade even as now.

Again, the air would be put in motion by the varying temperatures, and consequently winds would sweep the land and ripple the sea, waves would be produced by strong winds that would strike against the coastal rocks, beat upon the shores, and roll rock-fragments into smooth rounded pebbles. These winds, with the rotation of the earth, would take the courses they now have, and so there would be then as now trade-winds and anti-trades, as well as cyclones and hurricanes, and the monsoons and calms of the tropics. There would also be ocean currents, that would mingle the waters of the Cambrian seas, as they now bring the heated waters of the Gulf of Mexico to the North Atlantic. Still further, the sun and moon exerting their attractive force as now would raise a tidal wave that would in the narrow seas give with its ebb broad low-water beaches, and with its flow rolling high-water waves to attack the coast-cliff bases, and still further wear and round the shingle pebbles. The seas of the Cambrian epoch were likewise, as those of to-day, some deep and some shallow, for both deep-water deposits and shallow-water sediments make up the Cambrian rocks.

Climate would vary as at present with latitude and distribution of land and sea, and varying elevation of the land, and so all the conditions would be present to give graduated temperatures analogous to those that now in various lands range from tropical heat to arctic cold.

Throughout the millenniums of the Cambrian epoch night would follow day and day would follow night, daylight would lengthen and strengthen, and daylight would shorten and diminish; and in the temperate zones spring, summer, autumn and winter would complete the year, while in the tropics the rainy seasons and the dry seasons would alternate as now. These conclusions might have been drawn from even the larger and more general phenomena of the Cambrian rocks, but the beds of water-rolled pebbles, the ripple-markings, the sun-cracks, and the rain-pittings confirm such conclusions.

The palæontological evidence—the evidence of fossils—is as conclusive as the petrological evidence with respect to the character of the climatal conditions of the globe during the period of the deposition of the Cambrian rocks.

Although in the oldest of the Cambrians of the Longmynds of Shropshire and of North Wales the actual remains of animals are few and obscure, yet the paired or twin perforations in the sandstones can be none other than annelid borings, that tell of the existence of sand-worms, similar to those that abound on our present shores, and so confirm the evidence of tidal beaches furnished by the ripple-marks, sun-cracks, and rain-pittings. Casts of fucoids, too, tell of marine vegetation like that now growing on sea-bottoms. But when we examine the Cambrians of Pembrokeshire, we find remains of Crustacea of large size, and although the great family, the Trilobitidæ, has no representatives in present seas, yet trilobites in their general organisation so closely resembled the lobsters and crabs of the present day that they must have required a generally similar environment. Dean Buckland long since observed that the eyes of trilobites indicate that there was the full light of day when they lived. These wonderful organs of vision were sessile and compound like those of the common crab, though the lenses were round instead of hexagonal, as in our crustacean side-walking friend of the sea-shore, but the facets were so numerous that as many as fifteen thousand in each eye existed in some cases. Dr. Henry Woodward thinks the eye of the trilobite may best be compared with that of Limulus, and that there is an analogous development of visual organs amongst some of the pelagic Amphipodæ, the Hyperiidæ, and in a very singular form brought home by the *Challenger* expedition, the *Thaumops pellucida.*

In other Cambrian rocks, the Lingula Flags, there are abundant remains of Lingulella, a genus or sub-genus of a family of Brachiopoda, now well represented by the *Lingula chinensis* of eastern Asiatic seas. This is perhaps a more telling fact than the occurrence of an extinct group of Crustacea, for not only was the living body of the animal similar, and therefore suited only to similar general conditions, but the peculiar thin horny shell of the lingula of to-day was exactly represented by the shell of the *Lingulella Davisii* of the Lingula Flags, evidencing similar materials in both the Cambrian and the present sea waters of the globe, as well as the same physiological powers for its extraction and employment by the mollusc.

Perhaps, however, even a still more striking proof of the general cosmic conditions of the Cambrian epoch being the same as those of the present time is afforded by the occurrence in Cambrian rocks of species of a family of Lamellibranchiata, the Arcidæ, now abundantly represented by well-developed and, so to speak, robust species in our English seas. The Cambrian Arcidæ and the abundance of members of this family now give a conspicuous proof of the marvellous continuity of biomorphic types, or general organic form and structure, from early geologic times to the present; and that great as is the generally interesting character of this wonderful fact in itself, its significance or indirect teaching is exceedingly great also, for it clearly indicates the continuity of general inorganic conditions which must have existed to allow of the uninterrupted succession of generally similar organisms, all requiring, therefore, a generally similar environment for their existence and welfare, as well as for the development of the type. From the abundant evidence thus afforded of marine organic existence living in Cambrian times as it does to-day, we cannot doubt that the composition and density of the water of the sea were practically the same as now, and that both the sea and the atmosphere had the same relations to light, the same optic powers—the same absorptive, refractive, and reflective powers—as now.

The teachings, therefore, of stratigraphical geology, both petrological and palæontological, tell us in no uncertain way that the general inorganic conditions on the surface of the globe were during the Cambrian epoch very much the same as they are to-day. So clear and unmistakable is the evidence that we can with great confidence picture to ourselves the ancient Cambrian world. We can see, as it were, its lands and its seas, its spreading plains and elevated uplands, and its broad and deep seas, with their shallower bays and gulfs. On the land, too, are rushing torrents, rippling streams, and larger and smoother flowing rivers, carrying eroded material to the Cambrian ocean, fringed by sandy shores and shingly beaches. And the sky above is now an unblemished azure, now flecked with cirrus, and now dark with nimbus. Rain falls, winds blow, tides ebb and flow, and we can see the broad expanse of waters in their calm majesty, or, angry with storm and tempest, rolling mighty waves upon the Cambrian strand, and we can think of the millions of splendid sunrisings and gorgeous sunsets, and almost feel the heat of the noontide summer sun or the cold of the midwinter night.

We can even look through the clear salt water on to the ocean bed, and see the groves of algæ, with the trilobites and molluscs peopling those ancient seas, while along their coasts volcanic fires at intervals break forth, and lavas are outpoured that cover the surrounding rocks with basaltic or trachytic coatings. But save for these volcanic outbursts, the crash of thunder, and the roar of wind and wave, a silent world it was. No lowing herds or roaring beasts of prey were on the land, and no birds sang their songs, either on tree-top or high upon the wing. And how desolate was the unnavigated sea, for whales and porpoises, seals and sharks, and flying fishes were not in its waters, and no sea-bird's mew was heard, for no stormy petrel, gull, or penguin was upon its surface.

This is no fancy picture of a world of the imagination, but a picture of an actual world—a world that has been, a world that lasted millions of years, and a world that, unlike the airy fabric of a vision, has left many wrecks behind.

CHAPTER VII

THE WORK OF GEOLOGIGAL TIME—PALÆOZOIC

THE work that has been going on during the successive ages of geological time, the construction of the various rocks now forming the land areas of the globe, the building up of the habitable part of the world, has been continuous and progressive. But if it has been progressively constructive, it has also been largely destructive, since the material of each sedimentary formation has been derived from the rocks then forming the land of the globe which were in part destroyed. Thus there remain now only portions of the great sheets of rock which were originally formed by the accumulation of deposited material.

The geographical distribution of land and sea was therefore different, in some cases greatly different, in each succeeding period, and the present geography of the surface of the globe must consequently be regarded as the outcome of all the changes that have taken place up to the present time.

In the following slight sketch, and necessarily very imperfect outline, of this work of the time constituting the age of the world, it will be seen that the construction of the sedimentary rocks has been accompanied by a development of animal and vegetable life that in the main has been also progressive. There are now living life-forms far higher and more complex than any that the older rocks reveal, and very many of the lower forms that peopled the waters of the Palæozoic seas have become extinct.

Hence the changes, both physical and biological, which the surface of the globe has witnessed since it first became a solidified and cool exterior of the planet, have been progressive, leading up to present conditions. All the changes, indeed, revealed by geological investigation are but steps in the great march of cosmic events towards the production of present terrestrial conditions. And as these conditions allow not only of the life of mankind, but also of the increase and physical development of the human race as well as of the mental and moral growth of the human being, it must be concluded that all geological changes, which include palæontological, or ancient zoological, changes, have been the necessary steps for man's existence on the earth.

After referring to the analogies between the three living genera of Crustacea, *Serolis*, *Limulus*, and *Branchipus*, and the trilobites of Palæozoic times, Buckland, in his "Bridgewater Treatise," writes: "When we see the most ancient trilobites thus placed in immediate contact with our living crustaceans, we cannot but recognise them as forming part and parcel of one great system of creation, connected through its whole extent by perfect unity of design, and sustained in its minutest parts by uninterrupted harmonies of organisation."

Since the days of the fathers of modern geology many observers and writers have given assiduous attention to the great and wonderful story of the earth, which has been the subject of voluminous works dealing with various portions of the record of the rocks, and great is the accumulation of the results of the observation and researches of geologists in many lands. These records distinctly, and even conspicuously, tell of natural agencies working unchangingly, yet with effects differing in magnitude and intensity in different regions and at different epochs, but all the consequence of laws that know no change. Thus, although what is commonly called uniformitarianism in geology has been displaced by the present evolutionary geology, even as uniformitarianism displaced catastrophism or convulsionism, yet every geologist is, and must always remain, a uniformitarian with respect to the ultimate causes of the building up and sculpturing and conditioning of the present surface of the globe.

Below the Cambrian rocks, the oldest deposits containing distinct fossil forms, lie beds of great thickness that are obviously sedimentary rocks—clastic rocks as they are termed by geologists. These Pre-Cambrian or Archæan rocks include sandstones, limestones, and masses of graphite. The sandstones tell of the existence and the action of water, the limestones point to the existence of animal life and therefore indirectly to that of plant life, while the graphite points directly to vegetation existing in this early period of geological time. The geological action of water, consequent upon evaporation and condensation and the resulting rainfall, tells of alternations of temperature between 32° and 212° F., and the rocks themselves by their materials record vast destruction and reconstruction as well as subsidences and upheavals. These old Archæan deposits afterwards, by the slow elevation of sea-bottoms, became land, forming rocks, and even now, notwithstanding the destructive action of subsequent periods, they still form large land surface areas in both the New and Old Worlds.

The Cambrian rocks speak more plainly still, since in them are preserved distinct fossil forms, the enduring parts, or the casts of animals that inhabited the seas of the time of the deposition of the material of their containing rocks. Moreover, some of these rocks are conglomerates, or beds of cemented shingle, each pebble of which was rounded by the rolling action of sea waves, as is going on to-day at Brighton. Altogether these rocks, consisting chiefly of grits or hard sandstones, shales, and slates, have an aggregate thickness of 30,000 feet, again telling of vast destruction and reconstruction, and an altered geography of the world's surface.

The then existing land rocks furnished the material for the formation of the Ordovician and Silurian rocks, which accordingly indicate the continuance of the same physical changes, enormous destruction and reconstruction, with alterations of land and sea areas, which is the great lesson of the Archæan and Cambrian rocks. The Ordovician and Silurian rocks include sandstones and limestones and fine shales, some converted now into slates, telling of tranquil waters; and thick masses of volcanic rocks, both consolidated fragmentary ejectamenta, or ashes, and compact basalts, the result of violent eruptions and great lava flows, such as now at times devastate present active volcanic regions. In the uppermost part of the Silurians there is revealed the appearance on the earth of the highest sub-kingdom of animals, the Vertebrata, for in these rocks are the remains of fishes.

The overlying Devonian rocks are of great thickness, wide distribution, and of varied character. They give indications of large fresh-water areas as well as of wide and spreading seas with a well-marked development of fish-life.

Above the Devonian rocks are the great and varied and richly stored series of rocks called Carboniferous, that give to man at the present day his chief store of fuel, and yield besides much mineral wealth and useful economic material. The thick masses of the Carboniferous Limestone indicate a deep and clear sea abounding in corals and Mollusca, while the Millstone Grit and the Coal

Measures tell of widely spread shallow seas and occasional low swampy land surfaces, with mild or warm temperatures giving a profuse growth of plants. The Coal Measures have at present a wide geographical distribution, although they have, since the time they appeared as surface rocks, suffered great destruction. A notable example of this is afforded by Ireland, that once was almost covered by these industry-promoting deposits, but they have been so extensively denuded that only a few unimportant patches remain.

Although the conditions prevailing in the waters in which the known Permian rocks were deposited were evidently, from the greatly diminished fossil Mollusca of these rocks, unfavourable to animal life, yet the comparative abundance of amphibian forms is evidence of continuous progress towards present terrestrial conditions. Doubtless in other regions where the conditions were more favourable animal life abounded at this time, as in the previous and succeeding periods. The Permian rocks themselves indicate littoral, shallow-sea, and deeper-sea conditions.

As in the older so in the later Palæozoic ages, volcanic outbursts added igneous rocks to the sedimentary deposits, and they have greatly contributed to the picturesque beauty and varied elevation of many localities of the present time. Some of the basalts and hardened consolidated ashes have remained, and now diversify the surface as well as give volcanic material to enrich by its gradual decomposition the surface soils. Many of the hills of the South of Scotland, including the well-known Arthur's Seat and the Castle Rock of Edinburgh, owe their existence to the eruptions of volcanoes in Carboniferous times, as does the marvellous scenic beauty of the English Lake District to volcanic action in the Ordovician or Lower Silurian period. It should be added that the Palæozoic rocks as a whole form a vast storehouse, as it were, of economic minerals, available for use at the present time. Amongst the treasures which they contain, in addition to those peculiar to the Coal Measures, are gold and platinum, and the ores of silver, copper, mercury, tin, lead, zinc, and antimony, and immense quantities of iron ores. Many beds, too, of the Palæozoic rocks have been quite altered in structure, during the vast period since they were newly formed, by deep-seated transforming agencies, and so have now a lithological character that is of great economic value, as in the marbles and slates, and some, as quartzites, are of use as road metal. Others of these "Metamorphic" rocks, by their greater hardness and resistance to the destroying forces of nature, have contributed much to the higher levels of land areas, and in many cases they form the peaks and lofty summits of mountain ranges. The most picturesque and the grandest scenery is in regions where the Palæozoic rocks are prominent, forming as they do lofty mountains and bold hills, deep valleys with lakes and waterfalls, and irregular coast-lines with high and precipitous cliffs, which, as on the western sides of the British Islands, serve as protective ramparts against the destructive action of the sea.

The Palæozoic rocks are much more folded, more highly inclined, and more faulted as a whole than are the Secondary rocks. In not a few localities they are so much folded and uptilted that they now exhibit extreme contortion, and in some places are quite vertical. This may be seen in sections in all the divisions of the British Islands, and conspicuously in the Alps of Europe and the Appalachians of North America. In England, in Somersetshire, the older rocks are highly inclined, while lying on their upturned edges are approximately horizontal Secondary rocks. And in the same county the Palæozoic Coal Measures in the Radstock district are overlaid by Secondary rocks, through which many faults of the older rocks do not pass, clearly showing that these faults were the result of dislocations from earth surface movements, or seismic or earthquake action, in times previous to the formation of the newer rocks. This, however, need not be taken as evidence of greater frequency or greater violence of natural disturbing forces in Palæozoic than in Secondary times, but rather to the much greater length of time during which the older rocks have been subject to the action of these forces, both continuous and, in the case of faults, at intervals, sometimes separated by very lengthy periods.

CHAPTER VIII

THE WORK OF GEOLOGICAL TIME—NEOZOIC[1]

THE Secondary or Mesozoic rocks consisting of the Triassic, the Jurassic, and the Cretaceous, are markedly different from the Palæozoic rocks, as they are more varied in character, are much less disturbed from their original horizontality and much less faulted; nor do they contain those abundant results of volcanic action which are so marked a feature of the older rocks. Yet in places, as in the Jura mountains and even in England, in Dorsetshire and the Isle of Wight, Secondary rocks have been subjected to great folding pressures.

The lowest of the Secondary rocks, the Bunter, are sandstones and conglomerates, showing again great destruction of older rocks and deposition in a shallow sea of wide area, for they now form a large portion of England, and they are well known in Germany and further South. The old Bunter sea-beach may be actually now seen at Malvern, where the Triassic rocks rest against the eastern face of the Palæozoic hills, and the pebbles of this old sea-beach may be seen at Budleigh Salterton, South Devon, where many of these hard, well-rounded and smooth stones contain the Palæozoic fossils of the still older rocks from which they have been derived. Although, from being old sandy sea-floors and sandy and shingly sea-beaches, the Bunter rocks contain few fossils, yet the limestone that overlies them in Germany, the Muschelkalk, is crowded with fossil shells. This is most instructive, since it is a warning against concluding a general death or destruction of animal life to be the cause of a scarcity of fossils in any particular formation, instead of ascribing the cause to the insufficiently favourable conditions to life of the place at the time of deposition. Thus in sands and sandstones, as a rule, few fossils are met with, while in limestones and shales of the same general geological age and in the same area they are found in abundance.

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[1] Neozoic is here used to designate all rocks newer than the Palæozoic.

In England there is no Muschelkalk, but there are Rhætic beds in the Trias, largely limestones and shales, which are very fossiliferous. The Keuper beds, which in this country are between the Bunter and the Rhætic, are sandstones and marls, forming now wide-spreading plains and low elevations. The marls, which in places are very thick and yielding rock-salt and gypsum, would be formed by the drying up of shallow lagoons or salt-water lakes, and a depression would allow of the deposition of the material of the overlying

Rhætic beds as the base of the diversified Jurassic rocks which succeed.

The Jurassic rocks are a great series of beds mainly of alternating limestones and clays abounding with fossils of Mollusca having a marked approximation to present forms, with remains of great reptiles and small mammals as the first representatives of the highest class of the Animal Kingdom. With the exception of the Old Red Sandstone and the coal-seams with their underlying shales, the sedimentary rocks up to the Jurassic series are, from their fossils, obviously marine. But some of the Jurassic Oolites are estuarine and contain a large assemblage of land plants, in some cases beautifully preserved, which afford an indication of the character of the terrestrial flora of Jurassic times; and various beds of the Jurassic Purbecks, including the well-known Purbeck marble, are fresh-water deposits abounding with fossil fresh-water shells. Although the great bulk of the Jurassic rocks are limestones and clays, they indicate great destruction of older rocks forming land areas, since the calcareous rocks are composed of the material of previously formed limestones dissolved by water and so brought to the sea or lakes to form the coral rock and shells that ultimately became beds of Jurassic limestone, and the argillaceous deposits were derived from previous clays or from the decomposition of felspathic rocks. The easy disintegration of these Jurassic rocks, their varied character, and the level and gently undulating land they largely form, give favourable conditions for a varied agricultural produce.

Shallow-water conditions are indicated by the lower portions of the overlying Cretaceous series, and they have given besides a great estuarine formation or old river delta in the south-east of the British area. The higher portion, however, the Chalk, of over 1,000 feet aggregate thickness, shows a very considerable subsidence of the sea-bottom, with a resulting deep sea. The Chalk formation, indeed, furnishes a most interesting connecting-link with the present oceanic areas, since it is a rock of the same character and composition as a deposit now forming on the floor of the Atlantic Ocean. The Cretaceous rocks still remaining as land areas are, it may be said, world-wide in their distribution. They are both in the Old World and the New, and at the Antipodes as well as in the British Islands.

The stores of mineral wealth in the Secondary rocks, although not so vast and important as those in the Palæozoic rocks, are yet very great. They contain large amounts of copper and iron ores and gold has been obtained from the Cretaceous rocks of North America. Alum and gypsum are other useful substances which these rocks supply, and building stones, both limestones and sandstones, are very largely quarried from Secondary rocks, as well as the more ornamental stones, marbles, and alabasters, and various useful clays. But their most noteworthy British product is perhaps rock-salt, before-mentioned as occurring in the thick Keuper marls.

The geological work of Tertiary times was no less than the production in the rough, if that may be said, of those physical features and contours that now diversify the surface of the earth. The elevation of great mountain ranges, mountainous regions, and plateaux, though not of all, the cutting of river valleys, the spreading out of low plains, the formation of lakes, the separation of islands from the large land masses, and the production of coast-lines, as we now know these geographical features, were in the main the work of the Tertiary epoch. Some, it is true, of the great surface features of the earth have a much older date, and, on the other hand, considerable modification of the features of Tertiary geography has been accomplished by the unceasingly acting agencies of nature operating geologically all through the by no means short Quaternary epoch quite up to the present time. But it is still true that the present physical features of the land were in the main the work of Tertiary times. Miocene rocks are at an elevation of 5,000 feet in the Alps, and Pliocene strata are as high as 14,000 feet above sea-level in the Himalayas. To elevation during the Tertiary epoch is due the chief part of the height of the Andes in South America ; and the

Rocky Mountains in North America, in which Cretaceous strata are now 14,000 feet above the level of the sea, may also be termed Tertiary mountains, although, as in the case of the Alps, the Himalayas, and the Andes, part of the elevation has been effected in the older as well as in newer epochs.

Most of the active, and the more recently extinct, volcanoes are doubtless Post-Tertiary. In Europe, Etna and Vesuvius among active volcanoes, and the extinct volcanoes of Auvergne in Central France, and the Alban Hills of the neighbourhood of Rome, are all based on strata of Pliocene age, the end of the Tertiary epoch, and so may better be considered as Quaternary than as Tertiary features. But the great lava-flows that gave the basalt underlying nearly the whole of the county of Antrim, the igneous rocks of Mull, Staffa, and Iona, in the Hebrides, the great masses of volcanic rock of Colorado, Wyoming, and Nevada, in America, and the similar vast and wide extending volcanic masses of the Deccan in Asia and of Abyssinia in Africa, were poured forth in Tertiary times.

In the British Islands the work of geological agencies in the Tertiary epoch has left very conspicuous results. In the Isle of Wight, Cretaceous and contiguous Lower Tertiary strata are now so far altered from their original horizontal position as to be absolutely vertical. The denudation of the Chalk has been so great that, although from its protective covering of basalt the Chalk of the North of Ireland has been preserved, all the Chalk that once was continuous to the Chalk of Sussex has been swept away, except that to the south-east of a line from Dorset to Flamborough Head, and in this area the greater portion has been destroyed. When it is remembered that the Chalk formation has a total thickness of over a thousand feet, the denuding process that has destroyed so much of it will be at once seen to have produced most important changes in Tertiary times. In the South-east of England the Chalk extended over the whole of the Wealden area, connecting the North Downs of Surrey and Kent with the South Downs of Sussex. The forty or fifty feet thickness of pebbles constituting the Oldhaven beds, and forming still a large area in West Kent and East Surrey, is cogent evidence to every one walking over Blackheath or the Shirley Hills and Croham Hurst, of the enormous destruction of chalk that took place in early Tertiary times, for these beds are Lower Eocene, and every pebble is a highly finished, well-rounded fragment of a Chalk flint.

Of the geological work and the consequent geographical changes accomplished during the Tertiary epoch, Sir Archibald Geikie says: "The Tertiary periods witnessed the development of the present distribution of land and sea and the great mountain chains of the globe. Some of the most colossal disturbances of the terrestrial crust of which any record remains took place during these periods. Not only was the floor of the Cretaceous sea upraised into lowlands with lagoons, estuaries, and lakes, but throughout the heart of the Old World, from the Pyrenees to Japan, the bed of the early Tertiary or Nummulitic sea was upheaved into a succession of giant mountains, some portions of that sea-floor now standing at a height of at least 16,500 feet above the sea."

Although the Tertiary formations, as a rule, are comparatively local and indicate limited areas of deposition with various climatic conditions, yet there is one at least that witnesses to a sea of great extent, and this was the Nummulitic sea to which Geikie refers. The great sheet of limestone, called, from the nummulites it contains, the Nummulitic Limestone, extends from the west of Europe to the east of Asia. It is well known as furnishing the building-stone of the Great Pyramid of Egypt. The formation has a thickness of several thousand feet.

Evidence of great changes of temperature is furnished by the Eocenes of the immediate neighbourhood of London. The oldest formation of the Tertiaries in these islands, the Thanet Sands, well seen at Charlton, near Woolwich, was the deposit of a cold sea, while the London Clay was that of a warm sea. So near to London as Highgate, large nautili and other shells of a subtropical character are abundant in the London Clay, and in this formation at Sheppey the remains of seven species of turtles are associated with fossil tropical fruits in abundance. Again, at the close of the Tertiary epoch the fall of temperature was so great that it culminated throughout a large portion of the Northern Hemisphere in the Glacial epoch that has left so many mementoes of its existence in Great Britain.

In Miocene times, what is now the British Islands was probably a land area and so contains no deposits of this age. But Central Europe was then under water that extended along the line of the Alps, not yet raised to their great elevation, and the Pyrenees, and during the Miocene epoch marine gradually changed to brackish water conditions in this central sea. The result has been the accumulation of enormous deposits in Southern Europe and the basin of the Mediterranean, with the entombment of a magnificent assemblage of organic remains that presents us with a very vivid picture of at least the flora if not of the fauna of Miocene lands.

The records of the rocks which have here been presented, although briefly and altogether disproportionate to the greatness of the subject, will be perhaps sufficient to show that present terrestrial conditions are the result of innumerable links in a chain of events extending throughout a vast period of time, and that every one of these links was necessary for its successor; and that therefore all have been concerned in the production of the present terrestrial conditions. It may also be said that even the vastness of the time has been a most important factor in producing phenomena of everyday observation. For to it is due the great range of the character of the rocks, the extreme hardness of some and the softness of others, which now give the mountains and the vales. Moreover, the composition of the original rocks has been the source of all that is of value to mankind in our present rocks, and the various geological changes that have taken place have given the variety of rocks now at the surface that furnish the soils suited to the production of what the varied wants of man require. Regions there are for mining valuable minerals, regions for forest growths, areas for pasturage, and areas for the growth of the plants that give food and all the many valuable products of the vegetable kingdom. Still further, it may be said that the means of communication by water, the seas and rivers of the globe, by which mankind can intermingle, spread the products of the land, learn, and progress, and subdue the earth, have also been the result of the changes of the past. Nay, more, beauty and variety of landscape, beauty of field and flower, and even the charm of the music of the birds, have all been the outcome of this wonderful series of changes and modifications extending throughout geological time.

CHAPTER IX

BIOLOGICAL DEVELOPMENT—PALÆOZOIC

CONCURRENTLY with the building up of the great series of sedimentary rocks from the lowermost Cambrians to the latest deposits, the plant and animal life of the globe developed from the lower organisms of Cryptogams and Crustacea to the highest and most complex forms of life which are now to be found in the flora and the fauna of the earth. Probably, indeed, during nearly the whole of geological time there has been biological change and development, for the fossil crustaceans in the Lower Cambrians are the remains of comparatively highly developed animals, pointing to, if not demonstrating, the previous existence during the Pre-Cambrian epoch of lower or simpler organisms, although none have hitherto been with certainty discovered in the rocks of that early period of the world's history. But leaving out of consideration this Pre-Cambrian epoch, and taking only the time from the commencement of the Cambrian period, in the lower rocks of which epoch are well preserved remains of such well-developed animals as the *Olenellus* and *Paradoxides* of the Menevian

Beds of Wales and the Primordial Zone of Bohemia, there is undoubtedly a vast frame for the picture of organic form and organic change and development.

When we look at the bottom of this picture and then at the top, we are at once struck by the enormous change revealed. Although there were trilobites in the Cambrian seas with all the Classes of Mollusca abundantly represented in the Ordovician or Lower Silurian period, yet no vertebrates appear to have existed in any part of those most lengthy epochs. The backbone, the basis of the skeleton of the animals which to so large an extent people the earth and its waters now, was then non-existent, its advent being in a long subsequent Upper Silurian period. This remarkable morphological feature, the backbone, with its most important physiological attributes, is undoubtedly the most conspicuous differentiating characteristic of the Post-Ordovician fauna. Its appearance gave to the world the fishes of the seas, then the amphibians of the shallow waters, and afterwards the great dinosaurs, the pterosaurs, and other Reptilia, to be followed by the marsupials and monotremes of the land and the feathered birds of the air, with, long subsequently, the larger Mammalia in forms akin to those we know as living creatures, and lastly, man, the speaking and reasoning genus Homo.

It is the vast development of Vertebrata in both greater and lesser variation, in those great differences that constitute Class distinctions as well as in the smaller differences of genera and species, together with the great increase of individuals, that alters entirely the upper part of the great picture of life on the globe from the Cambrian times to the present. The appearance of the backbone marked, consequently, a most momentous period in the life-history of our planet, which seemed, as it were, to be a fresh starting-point for organic development. The concentration of the nerve matter of the animal in one cephalic ganglion, the brain, accompanied by an incipient and then by a developed vertebral column and canal, must be regarded as the greatest biological change that the fauna of the globe has undergone, inasmuch as it was the necessary step on the road to all subsequent developments of animal life.

But while this great development of vertebrate animals was in progress, changes by no means small were taking place in the Invertebrata also. An entire Order of Actinozoa, the Rugosa, disappeared, while three others advanced. Two Orders of Echinodermata, Cystoidea and Blastoidea, ceased to exist, and Echinoidea greatly increased. In the highest Class of the Mollusca, the Cephalopoda, many genera that are conspicuous in the Palæozoic rocks, as Orthoceras, Gomphoceras, &c., although tetrabranchs, are not to be found in Secondary rocks, while ammonites and the dibranchiate belemnites, of which there is no trace in the older rocks, are most conspicuous, both by their abundance and specific development, in Secondary formations, and again are absent in more recent deposits and at the present day. The dying out of species and genera of Gasteropoda, Lamellibranchiata and Brachiopoda, and their replacement by others between the Lower Silurian period and the Quaternary, are too numerous to be here enumerated.

And if the great picture of the biological aspects presented by this planet during geological time is strikingly vivified in its upper parts by the crowds of vertebrates, both terrestrial and marine, that are absent from the stiller world of early Palæozoic times, so is it abundantly enriched by the higher forms of plants that clothe the plains, the hilly uplands and the mountain slopes. In the Carboniferous period of the Palæozoic epoch, it is true, an abundant flora covered low-lying plains, but all the plants were cryptogams or gymnosperms. Magnificent ferns, equisetums and lycopods, grew thickly and rapidly where humid and warm conditions prevailed, but there were no trees such as those that form the forests of the temperate zone of to-day, or offer food to man on their fruit-laden branches, nor were there such flower-bearing shrubs as those that now beautify both cultivated and uncultivated lands. These, the higher forms of the Vegetable Kingdom, were reserved to make their appearance in Cretaceous times, and to develop in Tertiary times, until in the Miocene period they formed umbrageous woods and flowery glades that have left, for our inspection, admiration, and instruction, beautifully preserved leaves in great abundance, from which we see that many of our familiar friends of the woodlands and the hedgerows were flourishing long before the advent of man.

Thus both the Animal and the Vegetable worlds were enormously changed from Palæozoic to Tertiary times, rather by the introduction of new and higher types than by the extinction of species or genera. It is not too much to say that if all the Palæozoic species we know by their fossil remains had continued in existence to the present time, the difference of aspect of the whole fauna and the whole flora of to-day would have been slight. The fauna, however, of the Secondary epoch, with its huge armed dinosaurs and its flying pterosaurs, was markedly different from that of the Tertiary epoch, and therefore a great change was produced by the extinction of those reptilian monsters. The result of all biological change has, however, been to give to the globe a succession of higher and higher forms with greater complexity of structure and higher physiological power and capabilities.

Although a cursory statement only of the many steps in the long march of biological development would be far too lengthy for these pages, a review of the more noteworthy and conspicuous changes may be attempted.

In the rocks that were formed after the Cambrian, the Ordovician, as they are now called, but better known as Lower Silurian, are remains of higher Mollusca than those in the Cambrian rocks, for there are fossil gasteropods, pteropods, and cephalopods, some in great abundance. The trilobites and brachiopods of the Cambrians become more numerous and more differentiated, so as to give many genera of these groups.

A great step in the progressive march is indicated by the fossil fishes of the Upper Silurian, since they introduce Vertebrata. These were true fishes, certainly, but of an early type only. They were covered with bony plates of a reptilian character, but perhaps their most conspicuous difference from the usual fishes of the present seas was the form and character of the tail, to the extremity of which the backbone extended, giving it a prolonged pointed form. These heterocercle-tailed fishes, as they are called, have still many representatives in the sharks, sturgeons, and skates, but they are now less numerous than the homocercle, or equal-lobed tail, fishes which are now so common and abundant. In Silurian rocks, too, are remains of undoubted land plants, which Sir William Dawson described as Prototaxites, but now called Nematophyton, which was probably a thallophytal form.

The Devonian epoch saw a considerable development of Vertebrata, as the fishes were numerous, and though retaining the vertebral tail, diverged from the pristine type and approximated in the Upper Old Red Sandstone period to the modern salmon-like form. Large crustaceans, very much larger than our present largest species, the giant Australian crab—for they measured as much as 4 feet in length—abounded. As the beautiful Devonshire marbles conspicuously show, reef-building corals worked as industriously as now. During this period, too, there was a great development of plant life, both aquatic and terrestrial, including amongst the land-plants lycopods, equisetaceæ, rhizocarps, and an abundance of true ferns, Filices, vascular spore-bearing plants amongst the highest of the cryptogams. When the little likelihood of land plants being included and preserved in marine deposits is borne in mind, it is not to be wondered at that the far more ancient plants of Cambrian times have not yet been met with to give examples of the lower steps of the terrestrial flora.

A further advance is distinctly seen when the Carboniferous rocks are examined, for in these deposits there is evidence of the appearance on the globe of a Class of Vertebrata higher than the fishes of the Devonian rocks. This, the Amphibia, is represented by the Order Labyrinthodontia. The Amphibia, or Batrachia, best known now by our frogs and toads, are intermediate between fishes and reptiles. They are so similar in many morphological details to the more generalised fishes that Professor Huxley proposed the name of "Ichthyopsidæ" as an appellation for both fishes and amphibians. Insects were very abundant, and of forms still well represented, for the dragon-fly and a progenitor of the interesting little animal, the Blatta, so well known in London kitchens as the cockroach, were both flourishing in Carboniferous times.

But it is the wonderful preservation of the produce of plant-growth that gives to the Carboniferous rocks their greatest interest and their chief value to man. The coal-seams in these rocks are but consolidated masses, or beds, of vegetable matter grown on land or, at least, on swampy areas. This enables us to ascertain the biological level to which plant forms had attained in the Palæozoic epoch. It also shows that the climate then prevailing over a large portion of the earth's surface was warm, or at least very mild, for the vegetation in humid regions was as profuse as it is at the present day in the forests of the Amazon and other tropical river valleys. Nor were the Carboniferous forests wanting in stately arborescent forms, for lycopods attained a large tree-like size in Lepidodendron, and Sigillaria, which some think ought to have a higher position than Lycopodia, grew to a girth of 16 feet and a height of 50 to 60 feet. Equisetacea gave the genus Calamites in great abundance, while the ferns were most profuse and in a great number of genera and species, some of which are remarkably similar to those now to be seen growing so freely in the southern counties of England.

In the Permian epoch there was, as previously stated, a comparative abundance of amphibian forms, and indeed this period, though classed with the Palæozoic, may be regarded as intermediate between Palæozoic and Mesozoic or Secondary times, between the age of Invertebrata and fishes and the age of reptiles, birds, and mammals. The flora had a quite Carboniferous character, ferns being abundant and tree-ferns numerous. In addition there were some phanerogams, though confined to the gymnosperms, as remains of cycads and conifers are present in rocks of Permian age.

CHAPTER X

BIOLOGICAL DEVELOPMENT—NEOZOIC

THE Secondary rocks continue the record of change and development. Very many of the life-forms of the older rocks are absent, and thus tell of the extinction of a great number of species and genera and of some large groups. The most noteworthy absence is that of the entire group of trilobites, which were most abundant in Silurian times. These very well defined crustaceans ranged in time from the Lower Cambrian to the Carboniferous epoch.

Although the oldest of the three great divisions of the Secondary rocks, the Triassic, is not as a whole well adapted for containing organic remains, since the Triassic rocks are largely sandstones, yet one series of strata, the Rhætic, has been sufficiently preservative to yield decided evidences of a striking and most important advance in animal organisation, for in these beds are remains of an animal in the highest zoological Class, Mammalia. The *Microlestes antiquus* was a small animal of one of the lowest Orders of the Class Marsupialia, or pouched animals, like the Australian kangaroo, yet it was unmistakably a mammal, and thus the highest Class of the Animal Kingdom is found to have been represented in early Secondary times. Large batrachians were numerous, and their footprints on Triassic sandstones are common objects in museums. Insects, like those now seen, were abundant, and for the first time fishes with homocercle tails, the prevailing present type, appear.

In the varied and highly fossiliferous Jurassic formations, the rocks were formed during an epoch that has been called the Age of Reptiles, from the dominance of the large marine and the gigantic land reptiles which then peopled the globe. The enormous and terrible Dinosauria is an extinct Order of Reptilia, our present largest reptile, the crocodile, having a femur only one-sixth the length of the femur of a dinosaur. Another most remarkable extinct Order, the Pterosauria, flourished in Jurassic times. These extraordinary creatures were winged reptiles, the wings having a range of extension up to 24 feet. Although their wings were bat-like and not feathered, the pterodactyles had some of the characters of birds in conjunction with some that were reptilian. The remains of a true feathered bird, however, have been found in these rocks, showing that all the Classes of Mammalia were in existence in the Jurassic epoch.

Mollusca, with which Brachiopoda may be here associated, was represented by a very large number of genera and, of course, a much larger number of specific forms, with such a profuse abundance of individuals that some Jurassic beds are almost completely made up of their shells. Many of the genera are still living, and many of the species are only very slightly different from species in our present seas and lakes. One feature of the Secondary fauna is too remarkable to be here omitted. It is the incoming, enormous development of, and then the extinction of two well-defined groups of the Class Cephalopoda, ammonites and belemnites. Along with the Ammonite flourished the Nautilus of the same Order of Cephalopoda, the Tetrabranchiata, yet in Palæozoic times the Nautilus lived when there were no ammonites, and the Nautilus still flourishes, while the Ammonite ceased to exist at the close of the Secondary epoch.

Some of the beds of the Lower Oolites which are estuarine in origin contain a large assemblage of land plants that afford an indication of the character of the terrestrial flora of Jurassic times. From these fossil plants and parts of plants it is seen that this was a period of gymnospermous phanerogams. The prevailing Order was Cycadacea, about twenty genera of cycads having been described from Jurassic rocks, and the conifers were represented by the genera Araucaria, Pinites, Thuytes, and others.

The fauna of the Cretaceous rocks is noteworthy as well for what it lacks as for what it includes.

One of its lacunæ is the absence of mammalian remains in the European area, with the exception of a species ascribed to the genus Plagiaulax found at Hastings. Fishes of the highest type, the Teleostei, now make their appearance, and one genus, the Beryx, is not uncommon in the Chalk of Surrey and Sussex. With these are a large number of remains, chiefly teeth, of cartilaginous fishes allied to the present sharks. Of the Reptilia, the great Jurassic dinosaurs, although in some abundance still, die out with the Cretaceous epoch, and the same may be said of the pterosaurs. The reptiles have left some remarkable remains. Of these are the gigantic three-toed *Iguanodon Mantelli* of Sussex and Kent, and the still larger *Iguanodon Bernissartensis* of Belgium, which have been made well known by our museums; and the pterodactyles of the Cambridge Greensand. But it is to the rocks of the Western States of North America that we owe the greatest exposition of the reptilian forms of the Cretaceous epoch. From these rocks have been obtained many species of dinosaurs, pterosaurs, crocodiles, marine saurians, turtles, and no less than fifty species of veritable sea-serpents, of which the enormously long Mososaurus is best known. These dominating monsters of the Cretaceous seas were some as much as 75 feet long.

Although birds do not live under conditions favourable for the preservation of their bones, some remarkable species have been entombed in Cretaceous deposits, chiefly in North America. One group, Odontornithes, was toothed, and in the genus Hesperornis the teeth were in a common alveolar groove, as in the reptilian Ichthyosaurus. Thus some of the birds of the Cretaceous epoch had affinities with the then dying-out reptilian groups of dinosaurs and pterodactyles. In America, too, in the Cretaceous rocks of Dakota and Wyoming, a large assemblage of mammalian remains has been discovered. These have been placed by Professor Marsh in sixteen genera, but all are of the lowest Orders of Mammalia and allied to the Jurassic forms of the same Class. That remarkable Cretaceous rock, the chalk of England, as has been said, has been formed by the accumulation of deep sea microscopic shells. Some of the species of these minute testacea are the same as have been found in the deposit now being formed on the floor of the Atlantic Ocean, and one, the *Globigerina bulloides*, is abundant in both the Cretaceous rock and the present Atlantic ooze.

A very important advance in plant-life marks the Cretaceous epoch, for in its rocks are the remains, often beautifully preserved, of the earliest known angiosperms, which give at the present day the highest forms of the Vegetable Kingdom, and with these the phanerogams are also abundantly represented by the gymnosperms that marked the Jurassic epoch. From Westphalia alone 53 species of dicotyledonous angiosperms have been obtained from Upper Cretaceous beds. These include species of, amongst other genera, Quercus, Populus, Eucalyptus, and Ficus. In the Cretaceous rocks of other parts of Germany the phanerogams are represented by the genera Acir, Salix, and such conifers as Sequoia and Pandanus, the screw-pine. Another very remarkable feature of the Cretaceous flora is its extension, and in great abundance, to the Arctic regions, where in North Greenland are found remains of oak, walnut, plane, laurel, ivy, ilex, and even magnolia and eucalyptus. Again, in the uppermost Cretaceous of North America, the Laramie formation, 100 species of dicotyledons have been discovered, amongst which the vine, Vitis, is especially to be noted. The Potomac formation of Virginia and Maryland furnishes besides about 350 species of conifers, cycads, and lower groups, and 75 species of angiosperms, including the genera Sassafras, Ficus, Myrica, Bombax and Aralia. The epoch, therefore, during which the Cretaceous rocks were deposited, not only witnessed the existence of the highest Class of animal life, Mammalia, but also saw clothing the earth the highest division, the dicotyledons, of the highest Class, the Angiosperms, of the highest sub-kingdom of plants, the Phanerogams, or, in other words, the highest group of plants known to man.

The great development of the highest organic forms which distinguished the Tertiary epoch is abundantly testified by the records of its deposits. The highest group of plants was well developed, as we have seen, at the close of the Secondary period, but in the Animal Kingdom, the Orders Marsupialia and Monotremata were alone represented of the Class Mammalia, so far as is known, at that time. In the Tertiary formations, however, the fossils introduce us to higher and higher species, until in the latest deposits forms are found almost identical with species of the highest existing Orders. From the Eocenes of the Paris Basin remains have been obtained of a number of species of birds, which include forms allied to the living pelican, flamingo, quail, and hawk. And in these beds is the first appearance of the higher Orders of Mammalia, but the earlier species, although carnivores, have affinities with the marsupials, and then occur the bones of the Hyracotherium, a small pig-like animal with canine teeth. The Upper Eocenes, now called Oligocene, both of the Paris Basin and the Isle of Wight, have given a rich assemblage of mammalian bones. Baron Cuvier in France and Professor Owen in England worked at these bones with such success that they both arrived at the same conclusions, which established their accuracy. Thus Anoplotherium, Palæotherium, Xiphodon, and other genera of the Order Ungulata, were added to the fossil fauna of France and England. The Anchitherium was intermediate in structure between the tapir-like species just named and horses. It was as large as a small pony, but had three toes. With these, the earliest allied form to monkeys, the Cœnopithecus, appears, and hornless deer and antelopes seem to have been numerous in the Eastern Hemisphere. In America, again, there is a splendid assemblage of illustrative fossils. These include forms so distinct that Professor Marsh has proposed two new Orders or Sub-orders to contain them, the Trillodonta, uniting characters of ungulates, rodents and carnivores, and the Deinoceratata, resembling somewhat the rhinoceros, but as large as elephants. Most formidable were these great creatures with their six horns, two on the nose, two on the front of the skull, and one on each cheek. In the flora of the Eocenes there is found the important genus Olea, the olive of sub-tropical countries. The Miocene fauna is not so remarkable as the flora, but yet is sufficiently illustrative to show that it differed considerably from the fauna of the Oligocene epoch. The earliest elephantine animals are found in the great mastodons, and with them there was an enormous ant-eater, the Macrotherium, an early pig, the Hyotherium, a sabre-toothed tiger, the Machairodus, and a bear with affinities with the hyæna, the Hyænarctus. According to Gandry, the first anthropoid ape, the Dryopithecus, appears, but Owen thought it was more allied to the gibbons. In America, deposits of Miocene age have given the large Brontotherium, which is distinct from any existing family, but is nearest to the rhinoceros. The Miocene fauna is especially interesting from its giving the remains of the earliest dogs and camels. The genus Canis, of the Upper Miocene of Æningen, is related to the Hyænarctus already mentioned. The Protolabis of the Miocene of North America is regarded by some as the earliest camel, but the Pro-Camelus of rather later deposits, though still Miocene, is nearer to our present camel.

The Miocene fossil flora is especially remarkable, for the deposits of this age in lakes have beautifully preserved the leaves of the forests of the surrounding lands, and these have been carefully described and illustrated by Professor Heer of Zurich. In this flora there are remains of representatives of families of plants that have for a long period been of great use to mankind for fruit, for flowers, and for timber. Of fruit trees both Pomaceæ, giving our apples and pears, and Amygdalaceæ, giving our almonds and plums, appear, the former in Pirus, pear, and the latter in both Amygdalus, almond, and Prunus, plum. Rosaceæ, Violaceæ, Papilionaceæ, and Ericaceæ added floral beauty to the Miocene forests as they now do to our gardens. Of forest trees, the following genera, which were of earlier introduction, were in great abundance: Quercus, Ulmus, Platanus, Acacia, Acer, Ilex, Sequoia and Mimosa. The flora also included Magnolia, Betula, Laurus, Myrtus, Ficus, &c.

In the Pliocene epoch, the latest of the Tertiary periods and that which immediately preceded the advent of Man, the approach to present conditions both in the Animal and Vegetable Kingdoms is very conspicuously shown by the fossils of deposits of this age. The Miocene Deinotherium and Mastodon still lived, but they were now being supplanted by the true elephant, the rhinoceros, and by the hippopotamus, as well as by a large number of other herbivora allied to antelopes, deer, &c., indicating large grass-covered areas, together with the giraffe-like Helladotherium and Samotherium, and the Sewallik Hills of India give to the Pliocene fauna the Sivatherium and the Bramatherium. Now we find the true horse, Equus, and along with it the Hipparion, now extinct, which had three toes, but only one, the middle one, touching the ground. Now, too, there is the ox with the cat, the hare, and the mouse. The Mesopithecus and the Dolichopithecus were the apes of the period.

The flora of the Pliocene epoch was very similar to that of the present day in England, with the addition of one or two sub-tropical plants, and towards the end of the period the plants requiring most warmth disappeared, telling of a lowering of the temperature and an approximation to present climatal conditions. Besides the present forest trees of England, there was the buttercup, chickweed, dock, sorrel, marsh marigold, the *Osmunda* *regalis*, and many other plants with which we are familiar.

Although at the commencement of the Quaternary, or Human, epoch the climate in this and more northern regions was undoubtedly too rigorous for man, yet in more southern latitudes, to which the ice-covering conditions of the Glacial period did not extend, there would be no climatal hindrance to his existence. On the return of more suitable climatic conditions, man was undoubtedly living in these and adjacent areas. Judging from the large number of flint implements, showing design and intention, found in the Pleistocene gravels of England and France, human beings seem to have been tolerably numerous in the European regions soon after the rigorous glacial conditions gave place to a warmer temperature and a more genial and suitable climate. Thus biological development through the long geological ages led at length to its crown, the species *Homo sapiens*.

CHAPTER XI

IMPERFECTION OF THE GEOLOGICAL RECORD—PERSISTENCY

THE development of plant and animal life that continued throughout the period during which the sedimentary rocks were being formed was nevertheless marked by extraordinary persistencies and by very remarkable extinctions. These were both so remarkable that they well merit attention, the more so as they have been sometimes ascribed to causes not in accord with the great teachings of nature. Any adequate consideration of the causes of these phenomena must be founded upon, in the first place, a careful estimate of the facts revealed by palæontological research as to the time, character, and limitations of the continued existences of biological types, and not only with respect to the termination of the existence of species and genera, but also as to the morphological and physiological character of the species and genera existing both before and after these extinctions.

In the consideration, however, of the results of palæontological observation and research, we ought never to lose sight of that most important truth that all the geological data available, and all that ever will be available, for our use, must be but a most imperfect record of the past. The fossiliferous rocks now existing are but the remnants that have been left of those vast accumulated deposits formed in the past after having been subjected for enormously prolonged periods of time to the action of the destroying forces of nature. Thus, for example, not to go further than our own well-known islands of Great Britain and Ireland, the Jurassic rocks, now restricted to the south-east side of a line from Axmouth in Devonshire to the mouth of the River Tees, have left small remnants in the Hebrides and Sutherlandshire to attest their former extension over the area that is now Great Britain. The Cretaceous rocks, now confined to the southern and eastern counties, have similarly left small remnants in Mull and Morven on the west and fossils near Aberdeen on the east of Scotland; and as far north-west as Antrim in Ireland the uppermost formation of the Cretaceous, the Chalk, is found preserved by a protecting overlying sheet of hard volcanic basaltic rock, from which it is seen that this formation once extended over what is now England, the Irish Sea, and away to the extreme North of Ireland. A small outlier of the Woolwich Beds at Newhaven, on the coast of Sussex, shows the former extension of Tertiary deposits over the whole area of the older Cretaceous rocks now forming the surface between Croydon and the south coast. At St. Erth in

Cornwall there are remnants of Pliocene deposits 200 miles west of the nearest beds of this age. There is evidence therefore that the Jurassic rocks, now only in the Midlands and the south and east of England, once covered nearly the whole area now included in the British Islands and adjacent seas, and that the Cretaceous rocks, now confined to a still more limited area, had an equal, if not greater, extension; and the Tertiaries furnish grounds for a similar conclusion. The extent of Jurassic rocks removed, by the denuding or destroying forces of nature, from the region of these islands, not including sea areas, may be estimated at about 100,000 square miles, of Cretaceous rocks 110,000 square miles, and of Tertiary deposits 115,000 square miles, the total area of the British Islands being 121,700 square miles. So that in this region alone of the earth's surface only a very small proportion is left of these once widespreading Neozoic groups of formations.

Again, most extensive portions of the older and harder Palæozoic rocks have been similarly destroyed. Wide and important to the nation as is the present extension of the Coal Measures in the British Islands, those rocks with their valuable beds of coal have been denuded from much of the area over which in the pre-human era they extended. In the North of England the eastern and western coalfields were once continuous, but now they are separated by large moorland and hilly districts of older rocks without coal. In Ireland the Coal Measures once covered its interior area, while now almost the whole of these rocks, containing most valuable beds of coal, have been swept into the sea. The great unconformabilities and lacunæ are other obvious illustrations of the imperfection of the geological record. Under the London area Cretaceous rocks lie upon Devonian, while below Dover the Coal Measures have been reached immediately below Jurassic rocks as they are in Somersetshire. Still greater lacunæ occur in continental lands, as in a large area in the Balkan peninsula the Cretaceous lie upon rocks of Archæan age.

Of the animals and plants living at the time of the deposition of the various sedimentary rocks of the globe only a small proportion have left fossil remains, even of marine testacea, and of land animals and plants very few indeed, for the great bulk of marine shells would be broken up and destroyed by wave action, while of terrestrial animals and plants only the remains of those would be preserved that escaped decay and decomposition by entombment under exceptionally favourable conditions for their preservation. And finally, it must be remembered that only in a few places, each of very limited area, and aggregating altogether not one-millionth of their extension at the surface, have the sedimentary rocks been carefully examined.

But, very imperfect as this record of the rocks undoubtedly is, it gives, as far as it goes, a true revelation of the successive faunas that have peopled, and of the successive floras that have clothed, the globe. What it tells us is, therefore, so much positive knowledge of the highest value, although it be but a fragment of the great story of Creation.

Persistencies.—When the palæontological record is regarded as a whole it may be said that its most conspicuous feature is change, but if there was a general change in the morphology of animals and plants, there was also a marvellous preservation of some types and generic forms that have continued from even Palæozoic times to the present day with little variation. For when the wondrous picture is looked at more closely, and its details, both in its lower and its upper portion, examined, we are struck by the evidences of persistency of certain forms and structures, and, too, of the functional power and purpose of similar organs. Forms close to the bottom of the picture are similar to forms at the top, even the very top. So like do they appear that it requires close scrutiny by trained and expert observers to detect any difference. And when it is borne in mind that of the organisms existing in the far back Cambrian period only a few can have come to our notice, we must conclude that very many of the lower organisms of the present day are generically related to organisms of Cambrian times. This compels a recognition of the unity of the organic world, which must be regarded as one great biological chain without a break and with every link connected with another throughout geological time.

This persistency of organic form and physiological function may be well illustrated even by genera the remains of which are only to be found in the older rocks. Although the crustacean trilobites which were so abundant in Palæozoic times became extinct before the Secondary epoch, yet the Limulus or King Crab of the present day, especially in the young state, strikingly reproduces their main features, and the sessile and compound eyes of the common crayfish, crab, and lobster are almost identical with those of the Calymene and Phacops of Silurian times, in some of which trilobites thousands of facets in each eye have been counted. The four-eyed Limulus first appears in Jurassic, but the allied Neolimulus is in Upper Silurian strata, and the eurypterids of these Palæozoic rocks are scorpion-like also, and are now regarded as scorpionidæ and arachnidæ, although aquatic, the present scorpions and spiders differing in being air-breathers, even as land snails differ from aquatic gasteropods. There is, moreover, a true scorpion in Upper Silurian rocks, the *Palæophonus Hunteri*, while from Carboniferous strata no less than seventy-five species of arachnids have been obtained.

The graptolites are also confined to Palæozoic rocks, but they were structurally similar to the sertularians or sea-pens of the present day. Their habitat was similar, the functions of their organs were similar, their life was similar. And so it may be said of the still older Oldhamia of the lowermost Cambrians, that has not been found in any less ancient rocks, for it was structurally similar to some Hydrozoa of to-day. In Cambrian rocks, too, are fossil lamellibranchs and gasteropods of families that flourish in our own seas, as the Arcidæ, the Nuculidæ, and the Patellidæ, while Silurian genera of these Classes allied to living genera are numerous. These were in all respects similar to living species in all essentials of structure and physiological function. Again, the small Class Pteropoda that gives the little *Clio borealis* as food to the great whale of northern seas, gave the Conularia to Silurian seas, and specimens of these have been so wonderfully preserved that their fine striations, exactly like the fine striations of the glassy shells of the living Clio, are most distinctly seen.

In Cephalopoda, with one exception, Palæozoic generic forms were markedly different, it is true, from later and recent forms. The straight, the swollen, and the slightly curved forms of Tetrabranchia, so abundant in Palæozoic rocks, are almost absent from Secondary and quite absent from Tertiary formations, and the shell-less Dibranchia, that gave the multitudes of belemnites to the Jurassic and Cretaceous rocks, was absent from Palæozoic seas. Yet the essentials of the cephalopod of to-day were present in the Palæozoic cephalopods, and the chambers and septæ and the siphuncle of the living Nautilus were matched by the chambers and septæ and the siphuncle of the Lower Silurian Orthoceras, which was also four-gilled and so in the same Order, Tetrabranchia. The exception is the Nautilus itself, that not only has remained true to its Class, its Order, and its Family, but also to its genus from Palæozoic times to the present. Through all the varying marine conditions, the varying character of deposits, and the varying temperatures during the long æons between the Palæozoic epoch and to-day, the Nautilus has lived, and it is now flourishing in great abundance in the Indian and Pacific Oceans as *Nautilus pompilius*, the well-known "pearly nautilus."

The corals have lost an Order, but all the Palæozoic coral animals had the same physiological powers based on the same organs, with the same functions, as the corals of our present seas. It could obtain and secrete in a solid form the carbonate of lime in solution in the sea water, and with that secreted solid calcareous matter build a surrounding habitation exactly as does the coral animal of to-day. The Echinodermata has lost two Orders since Palæozoic times, but each of the existing three Orders, Asteroidea, Echinoidea and Crinoidea, was represented in the seas of that epoch, and the little Palæaster of the Silurian seas was quite like a little star-fish of our southern shores.

The early fishes had a peculiar structure, but it was not a structure peculiar to Palæozoic times, for there is the same structure to be seen in many living fishes. This was the extension of the backbone to the end of one of the lobes of the tail, the other lobe being merely a fin-lobe. And with this unsymmetrical tail the earliest fishes had an exterior coating of bony plates instead of scales. But in the sturgeon this type of fish still lives, and not in tropical waters or under exceptionally warm conditions, since sturgeons are often caught off British coasts, and, as is well known, they abound in the Russian Caspian Sea and the Volga. The sharks are also representative of the heterocercle tailed fishes, as they are called, but the majority of recent fishes have equal-lobed or homocercle tails. Even the peculiar Dipterus of Devonian age has its living representative in the both lung and gill possessing Ceratodus of Australia. Insects quite like those now living abounded in Palæozoic times, for cockroaches, crickets, beetles, dragon-flies, &c., were plentiful, and no less than 239 species of Orthoptera have been taken from Carboniferous strata. There are besides, in the Jurassic rocks, remains of earwigs, grasshoppers, white ants, may flies, and that genus of Diptera we know so well, the fly.

But perhaps the most striking example of persistency of form and structure and the continuance of the same physiological power, implying the same unctions of the same organs, is afforded by the little Lingula, a genus of the class Brachiopoda. The fossil *Lingulella Davisii* is in sufficient numbers in one of the divisions of the Cambrian rocks to give it the name Lingula Flags, and the Lingula is now living in abundance in the China seas. These two species are essentially the same animal. Their general form and size are similar, the character of the horny shell, in composition and structure, of both, was similar, and thus we see that the animal of Cambrian times was morphologically and physiologically allied to the Lingula of our own day. As might be expected, the Lingula is found fossil in many formations between the Lingula Flags and the latest deposits, and all the species show wonderful similarity.

In the plant-world, too, the persistence of types is conspicuous. The oldest land plants we know are ferns, very like recent ferns, and the Lepidodendron, Sigillaria and Calamites, of the Coal Measures, are lycopods and equisetums now abundantly represented.

Many other illustrations might be given of the great fact of the persistency of organic types and physiological functions, the numerous examples of which are well known to students of palæontology, but the facts now stated are sufficient to show that animal and plant life has existed with similar forms and similar physiological powers from the far back Cambrian period to our own times.

CHAPTER XII

BIOLOGICAL CHANGES AND EXTINCTIONS

If the conclusion be warranted that the cosmic inorganic conditions on the globe, however locally or even regionally varied, have been generally similar during the whole period of the deposition of the sedimentary rocks, and therefore during the whole period of life on the globe that has given all the information we possess of biological change, it must be further concluded, from the knowledge so obtained, that this change has accompanied in its progress small rather than great alternations and alterations of environing conditions. It is also evident from the testimony of the rocks that while great biological changes have synchronised with very small if any changes of environment, slight biological changes and even morphological continuance have accompanied considerable alterations of environing conditions. The marine conditions of the Ludlow could have been little different from those of the Wenlock period, during both of which argillaceous and calcareous matter was largely deposited, giving the Ludlow and Wenlock shales and limestones; and yet the fauna of the one gives us Vertebrata, which is absent from the other; corals and echinoderms greatly decreased; other Invertebrata greatly alter; and large arachnid crustaceans take the place of many species of trilobites. The British Permian deposits of sandstones and marls show similar marine conditions to those indicated by the Triassic sandstones and marls. Red and grey sandstones with conglomerates and stiff red marls make up 3,000 feet of the Permians of this country, and red and variegated sandstones with conglomerates and stiff red and variegated marls make up 3,000 feet of the Trias of England. Yet our Permian mollusca is wanting in our Triassic rocks, while the homocercle fishes and the dinosaurs of the Trias are altogether wanting in the Permian. Indeed, the Triassic rocks are much more allied lithologically to the Permian than to the Jurassic rocks, but the Triassic fauna is much more like the Jurassic fauna above than that of the Permian below.

The Rhætic limestones and shales of England are very similar to the Lower Lias limestones and shales, indicating similar marine conditions. Yet our Rhætic beds are without ammonites and belemnites, without many genera of Brachiopoda, Lamellibranchiata, and Gasteropoda, and without Ichthyosaurus and Plesiosaurus, all of which genera are most conspicuous in our Lower Lias. The

Bathonian and the Portlandian marine conditions, both giving thick-bedded Oolitic limestones, must have been very similar, but while Brachiopoda are most abundant in the Bath limestones they are entirely wanting in the Portland limestones, and although ammonites are present in both, belemnites are absent from the latter.

On the other hand, very considerable alterations of environment have been accompanied by very small biological change. Trilobites are in the shales as well as in the limestones of the Silurian rocks, although these greatly differing deposits indicate at one time abundant argillaceous matter in shallow sea water and at another a clear and deeper sea. So also do ammonites and belemnites abound both in the Jurassic limestones and the Jurassic clays, while in Cretaceous rocks they are both in the calcareous Chalk and the argillaceous Gault. The range in time of the Orders and genera of Cephalopoda, indeed, present several remarkable features. Tetrabranch cephalopods have lived through all conditions from Lower Silurian times to the present, while dibranchiate cephalopods appear in Secondary times. Two conspicuous tetrabranchs, the Nautilus and the Ammonite, with the dibranchiate Belemnite, flourished throughout the Secondary period under the same marine conditions, but at its close the tetrabranch Ammonite and the dibranchiate Belemnite became extinct together, while the

Nautilus which lived in Palæozoic seas continued to live and is still abundant. Again, the tetrabranchiate Orthoceras died out in Triassic times, while then it was that the Ammonoidea of the same Order had its greatest development, 1,000 species having been described.

And so it appears to have been with terrestrial organisms also, if we may judge from the comparatively few land fossils that have been preserved. Nothing could well be more different in land-surface conditions than the warm and humid and low-lying conditions of the Coal Measure areas, and the cool and breezy and elevated conditions of our mountain-sides. Yet the Pecopteris of the Coal Measures is very similar to the bracken of the upland slopes of England and Wales, from which we may conclude that the ferns, at least, of the Carboniferous flora flourished under very varied conditions of moisture and temperature all through the Secondary and Tertiary epochs. These remarkable and instructive facts doubtless present great difficulties, but they cannot be ignored, and must be taken into account in any adequate consideration of biological development.

Biological Extinctions. — A very remarkable feature of biological change was a series of extinctions, or the dying out of species, genera, and, indeed, of some Orders, by which both zoological and botanical morphology, especially zoological, have lost some highly specialised and, it may be said, picturesque types as living forms. But it must be borne in mind that many of what have been by some observers regarded as sudden extinctions have proved to have been more apparent than real. An apparent extinction may only have been occasioned by the migration of a species to another area, the rocks of which have not been examined or possibly have been destroyed. Extended and more careful research, too, has over and over again given a greater stratigraphical range to species and genera than had before been regarded as established. Species thought to be limited to a particular formation have been subsequently found in newer and, in some cases, much newer rocks. I have myself found species that were thought to be confined to certain formations in other beds, sometimes much higher, in the stratigraphical scale. This result of extended examination of fossiliferous rocks was well exemplified by the extension of the known stratigraphical range of the trilobite *Arethusina Konincki*, which up to a certain time had not been found higher than in a zone of the Upper Silurians of Bohemia, although in that and lower zones it was most abundant, and accordingly the species was considered to be quite characteristic of these rocks. But at length the *A. Konincki* was discovered in the much newer Upper Devonian rocks of Westphalia.

Such facts as these render it certain that future research will give similar results, and this forbids the conclusion that a species or a genus has become extinct at the time of the formation of the newest bed in which it has hitherto been found. Even those species of ammonites which are usually regarded as marking certain zones in the Jurassic rocks may not have had the relatively short existence that the small thickness of the strata they characterise may seem to indicate. They may have migrated to, and lived on in, other areas at a greater or less distance from that we have been able to examine. Although the theory or principle of homotaxis, as propounded by Huxley, cannot be allowed to apply to the extent its author anticipated, it yet has undoubtedly a considerable kernel of truth, for migration may entirely remove a species from a locality and give it to another where it will be contemporaneous with later deposits.

The difference in the fossil fauna of the same formation in two localities not very far apart is remarkable. If we take the Inferior Oolite of Gloucestershire and Dorsetshire, for example, we find an abundance of Brachiopoda in the former and an abundance of Cephalopoda in the latter. The *Terebratula subglobata* is most numerous near Stroud and almost absent in Dorsetshire, while almost only at or near Crewkerne in Somersetshire is *Ceromya Bajociana* to be found. From one small locality in Dorsetshire a large number of species of ammonites have been obtained, while in other localities the Inferior Oolite gives only a few of these species. Near Enslow Bridge in Oxfordshire the Great Oolite contains a bed in which *Terebratula maxillata* is most abundant, but any such congeries of this species is not to be found elsewhere. Yet in none of these cases is a species altogether confined to one locality, and as more and more places are examined, the evidence of wider extension is obtained. In two Austrian areas of contemporaneous Triassic rocks it has been recently ascertained that the fossils of one are very different from the fossils of the other, and that some remarkable zones with Palæozoic species are only to be found in one of these areas.

The very small area in which a number of individuals of a species may be localised, as it were, in a colony, is strikingly shown by the occurrence of that fine gasteropod, the *Purpuroidea Morrissia*. Thirty or forty years ago this fossil was abundant in the Great Oolite of Minchinhampton, while now it is not to be found there. The same bed is exposed, but the continued working of the quarry has removed a few horizontal yards of rock, which has obliterated the little colony, but only a colony, since it is not to be concluded that no other *P. Morrissia* lived in other areas on this geological horizon. At the present time there are thousands of cockles on our coasts in certain places and not a single cockle in others, even where the conditions are similar, and so it is with mussels, periwinkles, &c. If this is so, and has been so, horizontally, time will make it so vertically also, and this should give us pause before asserting that a species has become extinct because it has not been found so far in a bed above its so-called zone. It is indeed not too much to say that, until all the fossiliferous rocks in all parts of the world have been well examined, we ought not to positively assert the restriction of a species to a particular zone or even to a particular formation.

Doubtless, extinctions in geological time have been in the aggregate vast, but the time has been vast also. Some of the extinctions, it is true, have embraced not only species but genera, in a few cases families, and in a very few cases, only five in all, Orders, but these have, in most cases, if not in all, been effected during long extended periods of time.

CHAPTER XIII

CAUSE OF BIOLOGICAL CHANGES

It will be seen from the facts revealed by stratigraphical geology and by palæontological investigation that it will be most difficult to formulate a specific cause or specific causes for specific biological changes, including the appearance of new and the extinction of old forms. There is undoubtedly evident a great development of life-forms throughout the geological ages, and as regards geological time taken as a whole, there has been a progression from low and simple to the highest and most complex organisms. But the hypothesis of a continuous development is met by the great fact that cannot be ignored, that some newer species and newer genera were decidedly inferior to those preceding them of the same Order or Class, and thus apparently there were causes that for a time at least, and within a limited range, seem to have been acting to reverse advance, to retard progress, and to undo good.

The more complex graptolites are from Lower Silurian formations and the simpler forms from the

Upper Silurian and Devonian rocks. The largest and most highly developed genus of trilobites, the Paradoxides, is in Lower Cambrian rocks, while the two late Carboniferous genera, the Phillipsia and the Griffithides, are both simple and small. The earliest lamellibranchs were dimyarian and the much later Ostrea, Gryphæa, and others were monomyarian. The tetrabranchiate cephalopods flourished in Palæozoic seas long before the appearance of the dibranchiate genera. The Ammonite was not in advance of the Nautilus, which both preceded and survived it. And if Professor Hyat is right in saying that the efforts of the orthoceratite "to become completely a littoral crawler developed the Ammonoidea," it was a step that led to nothing further, since there is no genus that we can regard as being developed from the Ammonite, for the Nautilus is the only living tetrabranchiate.

The extinct Palæozoic brachiopods cannot either be said to be lower steps towards higher genera in Secondary times, since Terebratula, Rhynchonella, Discina, and Lingula all lived in Palæozoic times contemporaneously with Productus, Spirifer, Chonetes, Pentamerus, &c., and Lingula earlier than any. The two Palæozoic Orders of Echinodermata, Cystoidea and Blastoidea, passed away without being followed by any more highly developed successors, for the only three existing Orders of that Class, the Asteroidea, the Echinoidea, and the Crinoidea, were in existence as early as the two

Orders that have become extinct, so that the several Orders of Echinodermata were geologically approximately contemporaneous in their appearance. Though the pterodactyles had affinities with both reptiles and birds, they have passed away without leaving any developed successors, and the only creatures having affinities with them in their chief peculiarity are the mammalian bats. And, writing of fossil plants, the eminent botanist, Mr. William Carruthers, says: "Ferns, equisetums and lycopods, appear as far back as the Old Red Sandstone, not in simple or more generalised but in more complex structures than their living representatives."[1] It may indeed be said generally that in the case of very many species it is quite impossible to find any cause for saying that a newer is higher than an older form, or to see any reason in their structure for the order in time in which they have made their appearance.

But apart from these special instances, there is the great general fact of the introduction of new genera and species of lower Classes all through the Secondary and Tertiary epochs after the higher Classes of Vertebrata had come into existence. This is a most noteworthy phenomenon, since it shows that the Laws of Nature were employed in producing a Cardium, a Trophon, or a Littorina, in addition to the vast multitude of similar genera, occupying a similar position and playing a similar part in the cosmos, and when there were already much higher animals in existence.

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[1] *Geological Magazine*, 1876, p. 362.

Although the facts of palæontology are so multifarious, so varied, and in some cases so apparently inconsistent with each other, and even seemingly contradictory, that we cannot assign specific causes for them, the only conclusion that observation of Nature and acquaintance with Science and its methods seems to warrant is that biological changes with introductions of new and extinctions of old species are not due to any suspension or supersession of the Reign of Law, and that, therefore, however difficult it may be to explain the cause of specific changes, they are all due to natural causes.

In some cases, indeed, it does not seem difficult to suggest a cause of extinction, as in the case of the great dinosaurs of the Secondary epoch. These large creatures required much food, which sometimes might not be easily procurable, and their heavy and unwieldy bodies and very small brains would not assist them in their search for sustenance. So also the great mammals of the Pliocene and Pleistocene periods would be severely handicapped by their great food and water requirements when seasons were unfavourable, or changes of level or temperature altered the quantity or character for the worse of the plants on which they fed. Changes in physical geography, as Lyell long since pointed out, are capable of producing great effects on the flora and fauna of a region. By the slight subsidence of an extensive coastal plain it may be flooded by sea water and immense forests of trees and jungle plants destroyed, by which great herds of animals may lose the food on which alone they can thrive. Great swarms of locusts, again, have the power of devastating a wide extent of country, and so may deprive of food multitudes of small animals, by which large carnivora may lose their prey and so die of starvation.

In his great work, "The Principles of Geology," Lyell gives an interesting summary of the far-reaching effect of such an apparently small and unimportant thing as the transportation of a few polar bears by drift-ice to an island in northern seas before the time of man, such as Iceland has seen since its colonisation by Norwegians, who have been able to prevent the mischief by exterminating the invaders. In the absence of armed men and stronger carnivora, "the deer, foxes, seals, and even birds," on which polar bears sometimes prey, "would be soon thinned down. But this would be a part only, and probably an insignificant portion, of the aggregate amount of change brought about by the new invader. The plants on which the deer fed, being less consumed in consequence of the lessened numbers of that herbivorous species, would soon supply more food to several insects, and probably to some terrestrial testacea, so that the latter would gain ground. The increase of these would furnish other insects and birds with food, so that the numbers of these last would be augmented. The diminution of the seals would afford a respite to some fish which they had persecuted; and these fish, in their turn, would then multiply and press upon their peculiar prey. Many water-fowls, the eggs and young of which are devoured by foxes, would increase when the foxes were thinned down by the bears; and the fish on which the water-fowls subsisted would then, in their turn, be less numerous. Thus the numerical proportions of a great number of the inhabitants, both of the land and sea, might be permanently altered by the settling of one new species in the region; and the changes caused indirectly would ramify through all classes of the living creation and be almost endless."

When it is found that extensive areas have been elevated 14,000 feet since Pliocene times—for, as previously stated, in the Himalayas deposits of that age are now so high above sea-level—we must be impressed with the magnitude and vast number of geographical alterations that have taken place throughout geological time, and also with the almost infinite number of consequent possibilities that would affect, in one way or another, animal and vegetable life on the globe, and so be productive of biological change. The exact conditions of each period of geological time, and of each sea, and bay, and estuary, and lake existing in each of these periods, or each of the many and constantly varying land conditions of elevation, exposure, temperature, and humidity, we cannot hope to know, and so we cannot hope to be able to give the specific causes of specific changes, but the general cause of biological change does not appear so inexplicable.

"The fact of heredity is recognised," Dr. Saleeby says, "by every man who would show surprise on hearing that an acorn had developed into a human being or a mushroom," and "the man in the street need not leave the street in order to find conclusive evidence of the fact of variation."[1] But it is also necessary to remember that "the link which unites all organisms is not always the common bond of heritage, but the uniformity of organic laws acting under uniform conditions."[2] Heredity, variation, and environment, each acting in modification of the other two, and the vast duration of geological time, seem to furnish this general cause, and render less inexplicable the results of modern palæontological investigation, and we are therefore not called upon by these results to doubt that the Reign of Law is as supreme in the Organic as in the Inorganic world.

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[1] *Fortnightly Review*, 1905, p. 604.

[2] G. H. Lewes, *Fortnightly Review*, 1868, p. 373.

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